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INSPECTION

OF

RAILWAY MATERIALS

THE INSPECTION

OF

RAILWAY MATERIALS

BY

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WITH THREE PLATES AND NINETEEN DIAGRAMS

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PREFACE

THE present work is intended as a brief guide to the inspection of railway material for the use of engineers. It is confined to those parts of railway and tramway plant which are constructed of metal, and does not include woodwork and carriage fittings.

It has not been the Author's purpose to write a treatise on the strength of materials nor on the machines and apparatus for testing them—as on these subjects there are good works in existence—but rather to enable his readers to form a judgment in any particular case as to the class of material to be used in the construction of various parts of permanent way and rolling-stock, and the methods to be adopted for their inspection.

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THE INSPECTION

OF

RAILWAY MATERIAL

CHAPTER I

INTRODUCTORY REMARKS

Necessary qualifications of inspectors—Testing machines and tests—Weighing materials—Stamping—Methods of manufacture as bearing on inspection—Attendance of inspector at commencement of manufacture—Numbers of test-pieces—Certificates and reports.

THE inspection of railway material is a class of work for which every inexperienced neophyte devoted to the engineering profession imagines himself to be qualified. On the surface such inspection appears to be a very simple matter, and as far as the *modus operandi* is concerned is easy enough up to a certain point. In reality, however, many qualifications are required to make a good inspector, and chief among these is experience, the one most likely to be wanting in a young engineer.

Not only must an inspector be conscientious and reliable, but he must also have a fair knowledge of the processes by which the material he inspects is produced, of the manner in which it is applied and subsequently treated. Besides this, he should be thoroughly acquainted with the properties of metals, especially with regard to their strength, elongation, contraction, &c., and chemical composition. It may be imagined that he has only to adhere rigidly to the specification given him and all will be well. In practice this will hardly answer the purpose.

However rigid the specification may be, the judgment of the inspector always has to be exercised more or less. Absolute mathematical accuracy in rolled material, for instance, is never attained, so that 'in exact accordance with the specification' is only a relative term, and a too pedantic adherence to the letter of the law may do more harm than good in the long run. Besides this, there are many cases where no specification—or only a very general one—is supplied, and then the inspector has to rely entirely on his own judgment and experience. He must know in what points accuracy is of primary importance, and where and to what extent deviations from absolute accuracy are admissible. Moreover, what will satisfy one client may give rise to complaints from another, so that the idiosyncrasies of individual buyers of the material inspected (or of their engineers) have frequently to be taken into account.

It is always in the interests of the inspector to have a perfectly definite specification, so that the manufacturers know exactly what is expected; but this is not always attainable, and then nothing but experience and judgment will serve. Work that will answer very well for a light agricultural railway or for a horse tramway will not be admissible for an electrical tramway or a first-class railway, while for bridge and girder work a still higher standard is required.

For the inspection of rolling-stock and machinery, a trained mechanical engineer is essential: one who can distinguish between good, bad, and indifferent workmanship, and who knows the various degrees of accuracy proper to different classes of machinery, and also to different parts of one machine; where and when a sixteenth of an inch play should be allowed, or a dead true fit within one-thousandth of an inch exacted. Tests of material are usually carried out with the machines and apparatus in use at the contractors' works, and as a rule, with respectable firms, these may be relied upon as sufficiently accurate for practical purposes, since tests are being continually made, and it is in the interests of the manufacturers to keep their machines in fair working order. It would generally be impracticable to insist in every case upon checking a testing machine before consenting to accept the results obtained with it.

Where there is any doubt upon this point, the best

plan is to send samples to some testing laboratory, in which the results can be independently checked.

As a presumptive guarantee of the reliability of testing apparatus, it may be borne in mind that such apparatus is, at large works, continually being used by Government inspectors. Similar considerations apply to weights and measures, pressure gauges, &c. Measures can of course be easily checked, but in that case the inspector must be certain that his own measures are themselves accurate. It does not come within the scope of the present work to describe the various systems of testing machines in use, but it may be noted that for tensile tests the most accurate are those in which the load is measured directly by weights suspended at the end of a long lever, with a sliding jockey weight for the final adjustment. For convenience of observation the testing machine of Thomasset is one of the best. In this the pull on the test-piece is balanced by a column of mercury, the pressure due to which acts on a flexible diaphragm connected with one arm of a bell-crank lever, to which the test-piece is attached at one end. The pull is applied to the other end of the test-piece by means of hydraulic pressure. The load corresponding to the height of the mercury column can be read off directly from a scale placed beside the latter. For practical purposes this machine gives sufficiently accurate results. In the works where it is employed it is checked at regular intervals.

It is usual for the inspector to weigh about 5 per cent. of the material inspected in the case of rails and sleepers, as a check on the accuracy of manufacture, and sometimes the average weight per piece as thus determined is taken for calculating the weight of the whole delivery. This method is followed, for instance, by the official inspectors of the German State Railways.

Some works have adopted weighing machines with automatic recorders, on which every waggon-load is registered. The machines are in charge of sworn attendants.

As a rule, every piece passed by an inspector should be stamped with his monogram or other special device, and no piece not thus stamped is accepted as passed.

For very light articles, and bolts, nuts, clips, washers, &c., this is hardly practicable and is not usually insisted on; but frequently, when any class of material is packed in bundles or cases, each of the latter is stamped, a lead seal being provided for the purpose.

The method by which certain articles are manufactured may often affect the system of inspection, and, wherever possible, an inspector should always ascertain the manner in which the manufacture of the material subject to his control is carried out. As an example of this, the punching of holes in sleepers, rails, and fish-plates may be cited. Where, for instance, all the holes are punched simultaneously by dies attached to a single crosshead or frame, there is practically no possibility of

any important error occurring in the pitch of the holes, provided the dies have once been accurately set. When, however, the pitch is fixed by the interposition of distance pieces held by the workmen, there is always a possibility of error owing to the piece punched not being pushed home against the stops. Other examples of this kind will be mentioned in the sequel.

In the case of large and important orders it is very desirable—although not generally essential— that the inspector should be upon the spot when the manufacture is started, so that he may check the dimensions and weight from the very commencement and have any modifications effected that may appear desirable. In this way subsequent disputes and unpleasantness with the contractors may often be avoided. It is of course within the inspector's power to reject the whole or any part of the material whenever he pleases, before it leaves the works, but it is to the interest of every one concerned that any errors or inaccuracy in dimensions should be discovered before the manufacture is far advanced.

Test-pieces should be selected at intervals during the progress of the work, so that they form a fair sample of the bulk.

The number of test-pieces selected depends on the purpose for which the material to be inspected is destined, and also on the method of any circumstances attending the manufacture. In the case of boiler-plates,

for instance, test-pieces are taken from the edges of every plate; while, in the case of rails, at the most, but rarely, one test is selected for each charge. Whenever practicable it is a good plan to make at least one test for every charge (or blow). This affords a systematic check on the quality of the material, which is wanting when test-pieces are selected at random.

For every delivery of material passed, the inspector must send his clients a certificate of inspection, and before the material is despatched from the works the contractors should also receive a written notice that it has been accepted by the inspector; this notice may also conveniently take the same form as the certificate.

For Certificates and Test Reports it is preferable to use printed forms, samples of which are appended to the following chapters.

At the present day the inspector of railway material has to deal almost exclusively with steel; wrought iron being now employed only occasionally for rivets, bolts, nuts, chains, drawbars, and some minor parts of locomotives and waggons.

For firebox plates of locomotives copper is employed in Europe; but, in America, even for this purpose steel is largely used.

CHAPTER II

RAILS: ORDINARY AND TRAMWAY

ORDINARY RAILS: Types of rail—Sample specifications—Checking process of manufacture—Selection of test-pieces—Various kinds of tests—Number of tests—Systematic specification for drop tests—Apparatus for drop tests—Tensile tests—Influence of time on test-results—Drop tests at low temperatures—Chemical analyses—Hardness of steel for rails—Method of inspection—Section—Punching and drilling—Templates—Trying rail joints—Fit of fishplates—Length of rails; measurement and admissible margin—Weights: how determined, margin, &c.—Faults in material—Straightness—Memorandum form for recording results of inspection. TRAMWAY RAILS: Differences between ordinary and tramway rails—Sample test-results—Defects peculiar to tramway rails—Tiebar punching.

BY far the greater number of rails for use on ordinary railways are of the flanged or 'Vignoles' type; only in England itself is the double-headed rail in use; while on the Continent, in the Colonies, the United States, India, and South America, the flanged rail is all but universal.

Samples of specifications for ordinary rails will be found appended to this work. In their general tenor such specifications are all very similar, but vary considerably in the tests prescribed, more especially the 'drop' or 'falling-weight tests.'

The various points usually dealt with in specifications for rails will be taken in the order in which they require attention, although in this the inspector must often be guided by circumstances, and no invariable rule can be laid down.

As already stated, it is very desirable, especially in the case of large contracts, that the inspector should be at the works when the rolling is commenced, so that he may satisfy himself at the outset as to the accuracy of the section and weight; but this is not absolutely essential and often not practicable. In every case the section and weight of the rails must be checked after they are all completed, during the progress of inspection.

In some specifications the process of manufacture is prescribed, and in such instances the inspector ought to satisfy himself that the process specified has been actually followed.

It is, however, in the author's opinion a mistake to dictate in detail to manufacturers by what methods their work is to be done; the point of chief importance is that the *results* shall be satisfactory.

Tests.—The first matter requiring attention after rolling has been commenced is the selection of test-pieces. These should, as far as practicable, be taken from rails rolled at different times; for instance, when the rolling occupies several days, an equal number of test-pieces should be chosen from the rails turned out on

each day. Unless otherwise specified, the pieces of rail for testing may be taken from the crop ends or from the sound parts of defective rails, in order to avoid spoiling a good rail for the purpose. The crop ends are more likely to be defective than the rails themselves, so that if the results obtained from the former are satisfactory the inspector has no reason to suspect the latter.

Frequently the rails for tests are taken practically at random, and thus it may happen that two or more test-pieces are from the same charge or blow. In order to avoid this, it is now usual to stamp each rail with the charge or blow number on the web, about 12 in. to 18 in. from one end. Thus inspectors can select their test-pieces systematically from different charges. If a test from any particular charge is not up to specification, further tests from the same charge can then be taken in order to ascertain whether the defective test represents the bulk of the charge or not.

Tests for rails are of three kinds: drop or falling-weight tests, bending tests, and tensile tests; as a rule, however, only drop tests and tensile tests are specified.

The drop test consists in placing a length of rail upon supports from 3 ft. to 3 ft. 6 in. apart, and allowing a weight to fall upon it in the middle from a given height. The length of rail required for this is from 4 ft. 6 in. to 5 ft.

For the tensile tests it is usual to employ a test-piece of 1 in. diameter. The elongation is generally measured on a length of 8 in., so that the total length of the test-piece, including the heads at either end, is about 14 in.; if the elongation is measured on 10 in., then the total length must be about 2 in. greater. The test-pieces for the tensile tests are taken from the heads of the rails and must be cut out cold by planing and turning. The form of the heads depends on the system of testing machine used; but where the tests are made on the machine employed at the works, this is a detail which may be safely left to the contractors.

The pieces for the tensile tests are as a rule taken from the same rails as those for the drop tests; for the two test-pieces from each rail, therefore, a length of from 5 ft. 6 in. to 6 ft. is required. This should be stamped in two places on the head, in such a way that one impression is near the end of the length used for the drop test, the other near the end of the tensile test-piece; on the latter the part bearing the impression of the stamp must be left unturned, so that it can be subsequently identified. The unturned portion is left connected with the rest of the piece only by a thin neck, and is broken off before the piece is adjusted in the machine.

For bending tests, with a dead weight or pressure, a length of rail is placed upon two supports in the

same manner as for the drop tests. Pressure is then exerted at the middle, by means of a long lever with a weight suspended at the free end, the final adjustment being effected with a sliding jockey weight, or by a hydraulic press. The length of rail necessary is from 4 ft. 6 in. to 5 ft. Of course the weight of the lever itself must be taken into account in making such tests, but the allowance to be made for this is always calculated and tabulated in advance at the works having testing machines of the class in question. The figures supplied in such cases by the contractors, when given in a tabulated form which is in general use, may safely be taken on trust. As a rule it would be impracticable to check their accuracy by trial, but a rough check may be obtained by calculation, when the dimensions and proportions of the lever have been ascertained.

It is usually specified that a rail placed on supports 3 ft. to 3 ft. 6 in. apart must support a certain load in the centre for a certain time without showing any permanent set, and that with a greater specified load the permanent set shall not exceed a certain amount.

For measuring the deflection and set, the arrangement with which the author is most familiar is an apparatus in which these quantities are indicated on an enlarged scale by means of a pointer and circular dial, similar in appearance to a pressure-gauge. A pin projecting from the dial is so placed and adjusted that

it is just in contact with the underside (flange) of the rail before it is loaded. The motion of the rail is communicated through the pin to the pointer.

This arrangement has the disadvantage that if the rail flange is not quite true it may give way slightly under the load, and an apparent permanent set is registered which does not correspond to a permanent deflection of the rail. For this reason it is better to make use of an instrument such as that sketched in Fig. 1, which consists of a bar—preferably of steel—

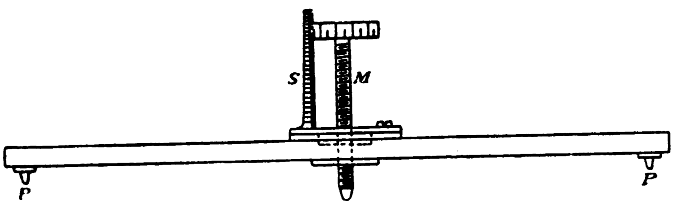


FIG. 1

furnished with two pins P P, at a distance from each other corresponding to the distance between the supports and equidistant from the centre of the bar. At the centre of the bar is a micrometer screw M, and scales for measuring the deflection, the sketch of which explains itself. The scale may be made adjustable about the centre of the screw, so that the micrometer can always be set at zero. The pins may easily be arranged for setting at various distances apart, say 3 ft., 1 metre, 3 ft. 6 in., 4 ft., and 5 ft. The screw and

measuring apparatus are drawn to an exaggerated scale as compared with the bar.

The instrument is shown in its simplest form, but is susceptible of refinements in detail, which will readily suggest themselves to the reader.

As a rule, when tests for rails are required, they are definitely specified, but cases occur in which the whole of the inspection is intrusted to the judgment of the inspector; while, in other instances, although no tests are asked for, it is still desirable to make them. Under such conditions the inspector cannot be as exacting in his requirements as when a specification is supplied, but he has nevertheless the right to satisfy himself that the material supplied is of a reasonably good quality before accepting it.

Number of Tests.—In many English specifications the number of tests to be made is practically left to the judgment of the inspector, it being simply stated that 'a certain number of rails, not exceeding 2 per cent. of the whole, are to be selected and tested in the presence of the inspecting engineer.' As a matter of fact, unless the tests are unsatisfactory, nothing approaching this proportion is tested. Generally speaking, about ½ per cent. is the usual ratio; it is, it may be noted, that adopted by some Continental State Railways.

Occasionally the number of drop tests required is greater than that of the tensile tests.

When so-called lever or dead-weight tests are prescribed, it is the general practice to make one of these for two falling-weight tests.

Drop Tests.—In no points do specifications differ so much as in the nature of the drop tests prescribed.

The regulations of the German State Railways regarding this matter will perhaps be the best guide, since they are at least systematic; according to these, the pieces of rail subjected to drop tests must not exceed 2 mètres, say 6½ ft., in length; the test-piece is to be placed on supports 1 mètre (3 ft. 3⅜ in.) apart and subjected in the middle to blows from a falling weight, of which the first blow must have a moment (= weight in lb. × fall in ft.) of not less than

21,700	ft. lb.	for rails	5	in. high and	weighing over	60·5	lb.	per yd.
14,500	„	„	4·72	„	„	55·5	„	„
10,850	„	„	4·32	„	„	46·5	„	„
8,700	„	„	3·94	„	„	40·5	„	„

The first blow is followed by blows having a moment of 8,700 ft. lb., until the deflection for a 5-in. rail reaches 4·00 in. For rails of other dimensions, the deflection must be inversely proportional to the height of the rail. After undergoing the tests, the rails must show no signs of fracture.

All large ironworks have a machine arranged expressly for carrying out drop tests. This machine generally consists of a framework of iron or wood, or both, carrying in bearings at the top a pulley, over

which passes a wire rope for hoisting the falling weight, tup or monkey (as it is variously called).

The weight is connected to the rope by a hook, with trigger gear, which can be disengaged in any required position by pulling a light rope attached to the trigger.

The bearings for the rail are formed by two heavy solid iron blocks or trestles, the distance between which can be adjusted according to requirements. The foundations for the framework must be very massive, and in some countries, in accordance with official regulations, must be open, so that they can be inspected at any time.

For measuring the deflection a wood or iron bar of rectangular section, with an adjustable straight rod or piece of strong wire passing transversely through the middle, is employed. The bar must have a length equal to the distance between the supports. The wire passes through a hole in the bar, in which it fits with sufficient tightness to remain without slipping in any position in which it may be placed. A more perfect form of this instrument is that in which the whole is made of steel, and the sliding rod calibrated and held in position by a thumb-screw. After each blow the bar is placed so that the ends rest on the rail exactly over the supports, and the wire is pushed through until the end comes into contact with the rail at the lowest point struck by the falling weight.

In the case of ordinary rails the falling-weight test is the most important, and some railway companies

specify this test only, or occasionally also a bending test under a dead weight, but no tensile tests.

Tensile Tests.—When tensile tests are required, but not definitely specified, the inspector may in the author's opinion be satisfied with a breaking tensile stress of from 35 to 40 tons per square inch, and an elongation of at least 12 per cent. in 8 in., provided the drop tests are satisfactory.

For the German State Railways only the tensile strength is specified, which must be from 40 to 44·4 tons per square inch; and it is worth noting in connection with this point, that rails rolled from material having a comparatively small elongation, will sometimes give very satisfactory results under the falling weight test. There is, however, no difficulty whatever in obtaining steel for rails with a breaking tensile stress of at least 40 tons per square inch, and an elongation in 8 in. of at least 18 per cent.

The test-pieces for tensile tests are always taken from the heads of rails, and should have a diameter of at least $\frac{3}{4}$ in. The elongation is generally measured on a length of 8 in. (or, on the Continent, 200 millimètres), between two marks made with a centre-punch. The diameter, where least, should be gauged with a micrometer gauge to within $\frac{1}{500}$ in. The diameter of the fractured section should also be measured in the same way, for the purpose of determining the contraction, when the latter is required.

The author always makes a point of observing, and generally of reporting, both elongation and contraction, whether specified or not.

As far as the author is aware, the time to be occupied in making a test is never specified and would be very difficult to regulate with certainty; it has, however, in certain cases a noticeable influence on results.

According to experiments especially made to determine the effect of time on test results, the latter are practically the same in the case of any particular quality of soft steel, whether the test occupies only two or three minutes or half an hour or more.

In the case of hard steel, however, a higher speed has a tendency to increase the tensile breaking stress and reduce the elongation and contraction. If the speed is diminished, the converse takes place: the tensile strength is somewhat reduced, and elongation and contraction increased. When a test-piece breaks very near to one end, the elongation and contraction are nearly always less than if the same piece broke in the middle; under such circumstances, if the results are not up to specification, a second test-piece may be substituted. A very slight flaw in a test-piece will also considerably influence elongation and contraction, although its effect on the tensile stress may be hardly noticeable.

Sometimes a test-piece, especially if of hard

material, will break off near the end, owing to its being jammed where held by the machine, or owing to the pull not being parallel with the axis of the piece; either of these causes may produce a bending stress, which reduces the apparent tensile resistance of the piece.

Effect of Temperature.—It is sometimes required that the falling weight tests shall be carried out with rails at a low temperature. This is the case with rails supplied to the Government Railways of Russia, on account of the cold winters prevailing in that country. The rails to be tested under these conditions are immersed immediately before testing in a freezing mixture of a given temperature, in which they are left sufficiently long to insure their being cooled throughout to the temperature of the mixture.

Extreme cold has been found to render steel of a certain hardness brittle with respect to impact; but, from numerous experiments made to ascertain this point, the tensile strength, elongation and contraction, are not appreciably affected by it.

Tests for Fishplates.—Fishplates are usually made of somewhat softer material than the rails for which they are required, say 28 to 30 tons per square inch, and frequently a bending test is also specified, which consists in bending the fishplates double round a bar of a certain diameter.

In the case of fishplates intended for patent joints, where the heads of the rails are recessed on the outer

side and the fishplates fit into such recesses in order to form a bridge—so to speak—over the joint, for the purpose of reducing the wear and deflection at the joints and also of rendering the running smoother, the fishplates should be made of the same material as the rails. These joints, as far as the author is aware, are only applied to girder tramway rails.

Chemical Analyses.—Chemical analyses of steel used for rails are often required by the specification, but the inspector is never expected to make these analyses himself. They are usually intrusted to some reliable analytical chemist and, it should be noted, are always charged for separately and not included in the inspection fee. The inspector must, however, frequently collect samples of borings from the material to be analysed. These borings are often drilled out of the test-pieces, and this is no doubt the most correct method, as it helps to establish a connection between the mechanical properties (tensile strength, &c.) and the chemical composition. It is better to have a separate analysis made of the borings from each piece, instead of mixing all together to form an average sample. One reason for this is, that in the event of there being irregularities in the composition of the various charges from which the samples are taken, these will not appear in an average sample; another reason is that separate analyses allow a comparison between the chemical composition and the mechanical properties to be made.

The drilling should not be effected too rapidly, as otherwise there is a chance of abraded portions of the boring tool becoming mixed up with the borings.

The borings forming the samples should all be bright; rusty or burnt portions should be removed.

On the connection between chemical composition and tensile strength, the author proposes to offer some remarks in a subsequent chapter.

Arrangements for Inspection.—Assuming that the tests are all satisfactory, the inspector may then proceed to the actual inspection of the rails and fish-plates.

The rails should all be laid ready on the benches in parallel rows, the ends as nearly as possible in the same straight lines, and the larger the number of rails that can be laid with their treads in one plane, the more convenient for the inspector. Frequently several rows of rails are arranged one above the other, and when the top row is inspected it has to be removed in order to make the row below it accessible.

The first thing to be done is to check the accuracy of the section. For this purpose templates, approved by the buyers of the rails, must be furnished, of the forms shown in Figs. 2 and 3. If, as is usually the case, a drawing of the rail accompanies the specification, the template, Fig. 2, should be carefully compared with the drawing. The counter-template, Fig. 3, must fit exactly the template, Fig. 2.

Assuming both to be correct, template Fig. 3 is tried against both sides of the rail and should fit accurately, especially as regards the angles of the surfaces against which the fishplates abut. In the width and depth of

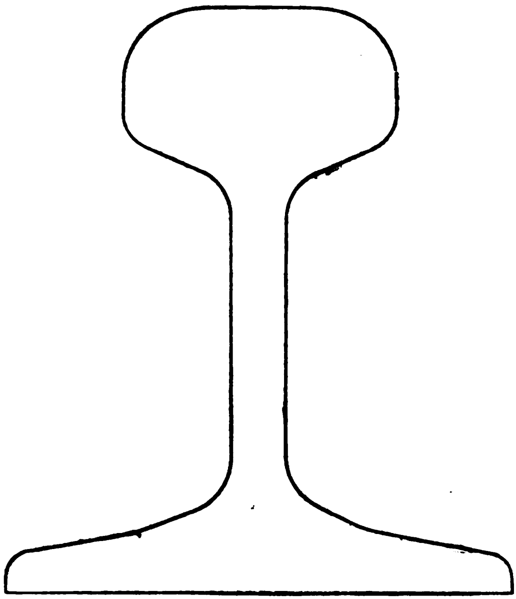


FIG. 2

the head, width of flange, thickness of web, and height of rail, a slight margin of error is admissible: $\frac{3}{64}$ in. in the width of flange, and about $\frac{1}{32}$ in. in the other dimensions. The section of all the rails, however, must be exactly similar, and the same at all points in the length.

It is not as a rule necessary to check the section of every rail, but this should be done at equal intervals

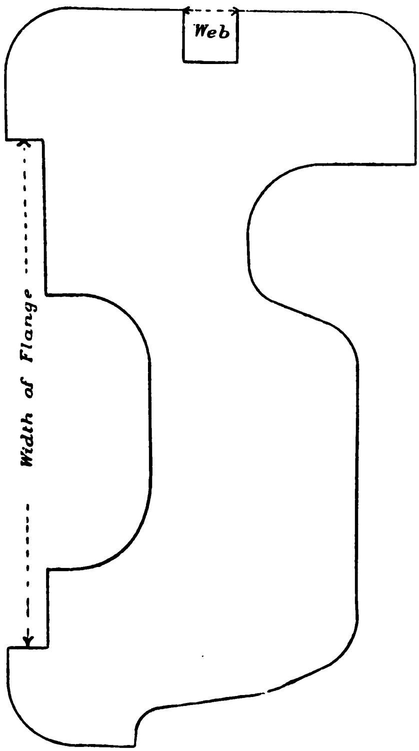


FIG. 3

along the rail benches. In passing by the ends of the rails, the inspector should notice those that have any obvious irregularity and try such with the template.

It occasionally happens that rails made in trying the rolls, before they have been accurately adjusted, get mixed up with the other rails. The defects of these are usually quite obvious to a careful observer, and such rails should of course be rejected.

Punching and Drilling.—The next point requiring attention is the punching or drilling of the bolt-holes for attaching the fishplates. These must be checked as regards both dimensions and position, and for this purpose gauges must be provided by the manufacturers. One of these, shown in Fig. 4, is for checking

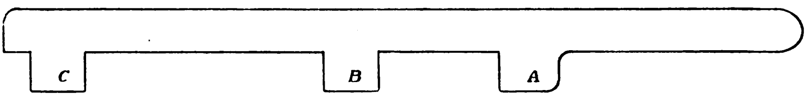


FIG. 4

the pitch of the holes, their distance from the end of the rail, and their dimensions in the direction of the longitudinal rail axis. The two projections at C and B should fit easily into the holes, and that at A should just clear the end of the rail. For checking the position of the holes with reference to the head and flange of the rail, the second gauge, Fig. 5, is necessary.

The projection at A has a width equal to the dimension of each hole in the direction perpendicular to the rail axis. The edge, C C, of the gauge must be in contact with the lower surface of the rail flange, while the projection, A, fits easily into each hole.

Besides this gauge it is very desirable to have another for testing the vertical position of the holes *with reference to the fishplate.* During the progress of rolling it frequently happens that the depth of the rail head or

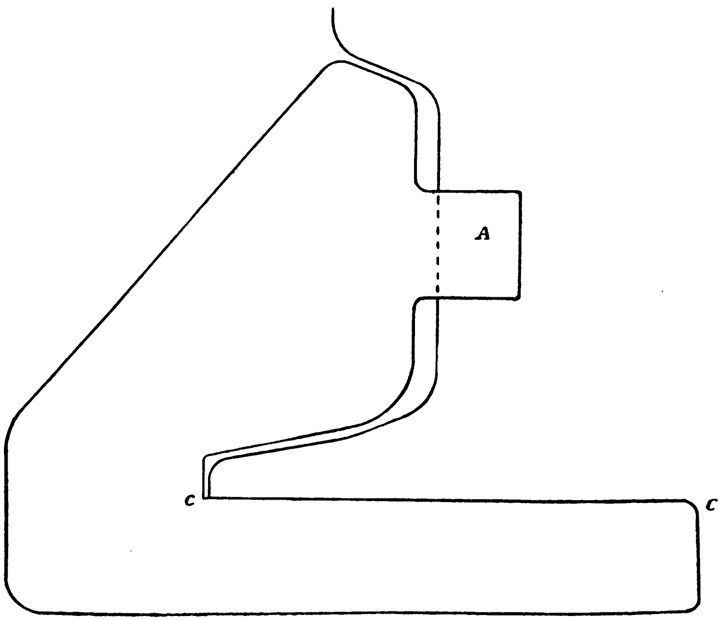


FIG. 5

the thickness of the flange increases somewhat, owing to the wear of the rolls. If only one of these alterations occur, it has the effect of altering vertically the position of the fishplate relatively to the rail, and consequently the holes in the fishplate are either too low or too high

with reference to the holes in the rails. To make sure that this deviation does not exceed admissible limits, the gauge shown in Fig. 5A should be used; the construction is obvious from the illustration, without further description.

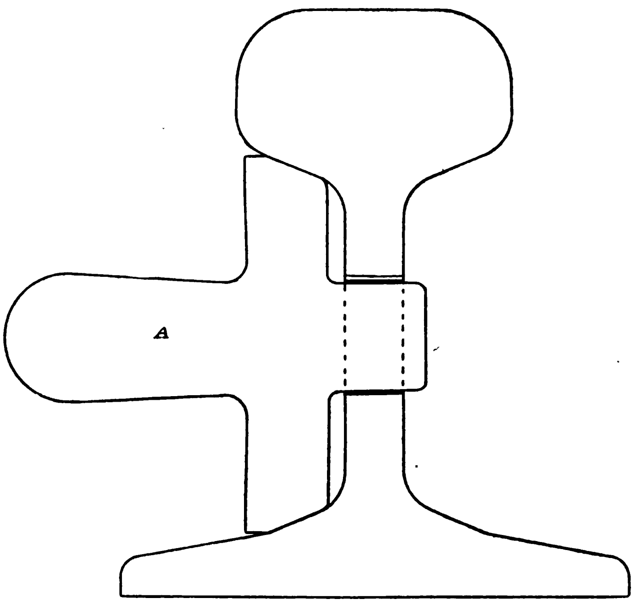


FIG. 5A

For checking the dimensions of the fishplates themselves, the gauges illustrated in Figs. 6 and 6A must be employed, besides a template having the exact form of the fishplate section.

The gauge, Fig. 6, is for checking the form of the

back and front of the fishplate and also its thickness. The gauge, Fig. 6A, is for testing the accuracy of the punching or drilling of the holes in the fishplates, with reference to the width of the latter.

For checking the longitudinal position of the fish-

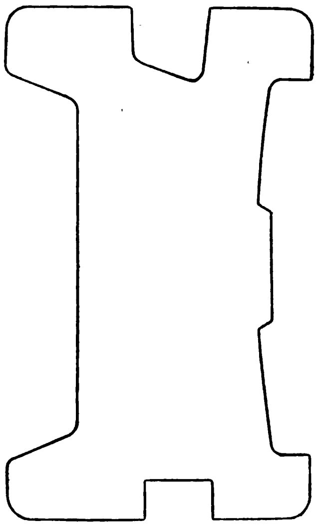


FIG. 6

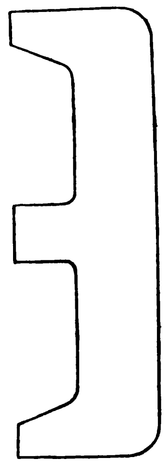


FIG. 6A

plate-holes, a gauge is used similar to that employed for the rails and shown in Fig. 4.

It is frequently specified that no error exceeding $\frac{1}{32}$ in. shall be admissible in the position of the holes. Apart from this, the main point is that the holes in the rails correspond with those in the fishplates, and it is

better that they should be a trifle large than too small.

It is desirable to check the longitudinal position of the holes *for every rail*, and this can be conveniently done at the same time that the length of the rails is measured.

If all the holes at one end of each rail are punched or drilled simultaneously, there is practically no risk of error. Very frequently, however, the end of the rail is pushed up against a fixed stop and the inner hole first punched; a loose stop is then inserted for fixing the pitch of the other holes before punching. Errors occur owing to the rail not always being pushed home against the stops.

Several pairs of rails should be bolted together with their fishplates, and the dimensions and pitch of the holes in the latter checked in the same way as the rail holes.

The ends of the rails must correspond accurately when fished together, and there must be a space of from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. between the ends of the rails; there is usually plenty of clearance in the holes for the bolts, so as to allow for expansion, and the distance between the rail ends can be varied considerably. When the rails are bolted together with the specified amount of clearance, the centres of rail and fishplate holes must correspond.

The bevelled edges of the fishplates must be in

contact with the bevelled surfaces of the flanges and heads along their whole length. If the nuts of the fishbolts are screwed up tight, the points where the fishplates have been in contact with the rails can generally be seen when the fishplates are removed; these points should be evenly distributed over the surfaces.

The inspector can get the rails and fishplates selected for the purpose bolted together while he proceeds with the inspection of the bulk.

Length.—The length of the rails is measured by means of a long steel or iron flat bar about 1 in. wide and $\frac{1}{4}$ in. thick. At one end (see Fig. 7) this bar is furnished with a projecting stop, from which the lengths required are measured and marked on the bar. At the same end as the stop and beyond it, is a handle, while the other end is carried out considerably beyond the greatest length to be measured, so that a man standing a foot or more away from the rail ends can conveniently take hold of it. One man holds the measuring bar by the handle, while a second grips it at the other end, and it is then applied to each rail in succession. The bar is laid on the rail to be measured

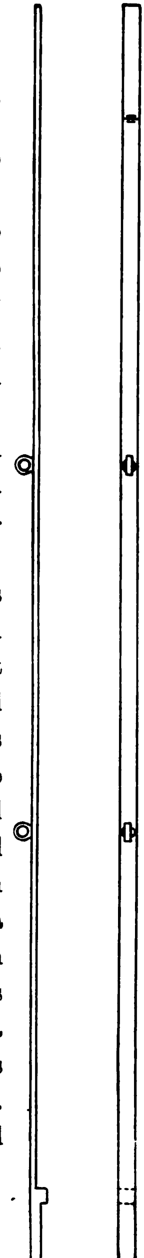


FIG. 7

and pulled tight, so that the stop is in contact with one rail end. The inspector follows the man holding the end at which the length is marked, and notes whether it corresponds with that of each rail. Generally a certain margin of error is allowed—for English rails usually $\frac{1}{4}$ in. to $\frac{3}{16}$ in., for Continental rails 3 mm.—and it is a good plan to set out this margin on either side of the mark indicating the exact length. In the case of long rails a third man, walking on the top of the rails, supports the measuring bar in the middle by means of a wire loop or hook.

It is most convenient to measure the rails when lying on one side, and, as before mentioned, the punching can be checked at the same time.

For light rails, say 9 lb. to 20 lb. per yard, a greater margin of error in length is generally allowed: $\frac{5}{16}$ in. to $\frac{3}{8}$ in.

Weight.—In order to ascertain whether the rails generally have been kept within the limits of weight specified, a number should be weighed separately. As already mentioned, it is usual on the Continent to weigh about 5 per cent. of the total, and in the case of some Continental State Railways, the average weight of a rail thus determined is taken to represent that of the whole quantity.

It is very usually specified that no rails will be accepted which vary more than 2 per cent. above or below the normal weight, while the variation of the total must

not exceed 1 per cent. It is important that rails should not be too light, as this indicates deficiencies in the dimensions; excess of weight is not in itself so great a drawback, and the buyer is generally chiefly concerned to be sure that he has not to pay for excess weight.

Very light rails, for portable railways, mines, &c., may be weighed in lots of twenty to fifty at a time.

Single rails should be weighed by means of a balance, as this is more accurate than a decimal weighing machine.

Occasionally it is specified that the normal weight of the rails is to be fixed by weighing, say, 100 rails of perfectly accurate section from the first rolling. The resulting weight is then taken as the standard.

Inspection for Faults.—After measuring the rails and checking the punching, the next step is the inspection of the rails for faults.

When measuring the rails it is desirable, in passing along the ends, to notice whether there are any cracks or defects in the latter, but this may also be done afterwards. Assuming the rails to lie on their sides, the inspector walks backwards and forwards on the top of the rails, parallel with their longitudinal axes, commencing at one end of the row, and carefully examines the parts uppermost for flaws, cracks, scabs, blisters, sands, ragged flanges, and other defects.

In the case of fairly heavy rails, four or five can be conveniently inspected at once in walking across from

one side of the row to the other; so that if there are, for instance, 200 rails in a row, it will be necessary to pass twenty to twenty-five times in each direction, from one side to the other, in order to examine the whole. As the inspector advances, the rails should be turned with their flange surfaces uppermost, and the process of inspection is repeated in the same manner as before.

The rails are now turned again, so that the side opposite to that previously inspected is exposed, and the inspector walks over the rails for the third time. Finally, the rails are placed so that they stand on their flanges, and the heads are then carefully examined. For rails of average or heavy section the author has found it most convenient to look over only three rails at a time, as the head of the rail is the most important part, and it is not so easy to detect faults here as in the case of the flanges.

In going over the rails, the inspector starts each time from the same end of the row. When the rails have thus been inspected on all sides, they are finally examined for straightness. For this purpose the inspector stands on the ground at a distance, if practicable, of 6 ft. or 8 ft. from the rail ends, and walks slowly along the whole row, looking along each rail as he does so to see if it is free from 'kinks,' or sharp bends.

It is preferable to go through this process from *both* ends of the rails, as it is not always easy to detect a

kink near the end at which the inspector stands, especially if he has not room to place himself a considerable distance off. Straightness, both in a lateral and vertical sense, must be looked to, although faults more frequently occur in the former.

In the case of light rails, a larger number than that previously mentioned may be looked over at once; but this is a matter which must be left to the judgment and experience of the inspector.

Rails (and other rolled materials) should always be inspected as soon as possible after rolling, before they have had time to rust; they ought also to be dry when inspected, as it is more difficult to see defects when the surfaces are wet.

Defective rails should be marked with chalk at both ends, or better still, with a special stamp. Rails requiring straightening only should be marked in a special manner to indicate this; they are then removed, straightened, and placed a second time before the inspector. Rails must be straightened cold.

As each row of rails is inspected, the number passed should be counted and noted by the inspector, who then has each one stamped with his own stamp at both ends.

For recording the results of inspection, the following form of memorandum is convenient: the figures at the head of the vertical columns give the lengths of the rails; the numbers opposite each date the numbers of

each length of rail inspected on that day; the rest needs no explanation.

Date	30′	28′	26′	24′	21′	Fish	
June 1	400	12	10	6	2		
,, 2	350	6	4	4	4		
,, 3	550	10	2	8	6		
	1,300	28	16	18	12	1,400 prs.	
lb.	800	746·66	693·33	640	560	15	{ Unit weight
lb.	1,040,000	20,907	11,093	11,520	6,720	21,000	{ Total weight

It is also a good plan to note the number of rejections in each bench of rails inspected.

Faults in Material.—The faults which most usually occur in the material of rails are generally catalogued under the heads of scabs, blisters, cracks, sands, ragged flanges, bad ends, and sponginess; to which may be added, more especially for tramway rails, wavy or corrugated webs. There is no object to be gained by a minute description of the various classes of faults, which 'must be seen in order to be appreciated.' In the following illustrations a few faulty lengths of rail are shown. Some faults are less easily seen than others, and generally speaking it is not so impossible as might be supposed to overlook even serious defects, especially when the light is unfavourable.

Frequently faults occur which are more easily seen from one side than from another, and therefore it is a good plan, when passing over the three or four rails which form the immediate object of the inspector's scrutiny, to also keep an eye on those which have just been traversed in the opposite direction. For this reason the author is not in favour of the plan followed by some inspectors, of having only four or five rails turned over at once, and completing the inspection of these before passing on to the next, as in this way a chance is lost of subsequently discovering defects which have been previously overlooked.

TRAMWAY RAILS

For tramways so-called girder rails, with a groove rolled in the head, are now almost exclusively employed, and it is to these that the following remarks apply.

In the main, of course, the inspection of tramway rails is the same as that of ordinary rails, but owing to differences in form, in the manner in which they are laid, and in the treatment to which they are subject, as compared with railway rails, there are a few points in connection with tramway rails which call for special notice.

As a rule a somewhat harder steel is employed for tramway rails than for railway rails, as owing to the grit and dust in streets, the greater frequency of the

traffic, the larger number of stoppages, and the passage over and across them of ordinary vehicles, tramway rails are subject—in large towns at any rate—to greater wear and tear.

The steel used should have a tensile strength of at least 40 tons per square inch, with a minimum elongation of 15 per cent. in 8 in. Very frequently only the ultimate tensile strength is specified, but, even in such cases, with material supplied by manufacturers of good repute, the author has almost invariably found the elongation to be 15 per cent. and the contraction of area 40 per cent. with the above-named tensile strength.

Within the last two or three years the ultimate tensile stress of steel used for tramway rails has gradually increased, and now at least 44 tons per square inch is very generally expected, while 48 tons is not unusual.

The elongation with the latter stress is from 12 to 14 per cent.

When the drop test is not definitely specified for tramway rails, the author usually adopts the following:

Falling weight $=1$ ton; distance between supports $=3$ ft.; for rails up to about 70 lb. per yard and not under 45 lb.: the first blow from a height of 5 ft., the second from a height of 10 feet; for rails over 70 lb. per yard, a third blow from a height of 15 ft. may be given.

Owing to the manner in which they are rolled,

grooved tramway rails are subject to irregularities in section from which ordinary rails are free. These irregularities occur chiefly in connection with the

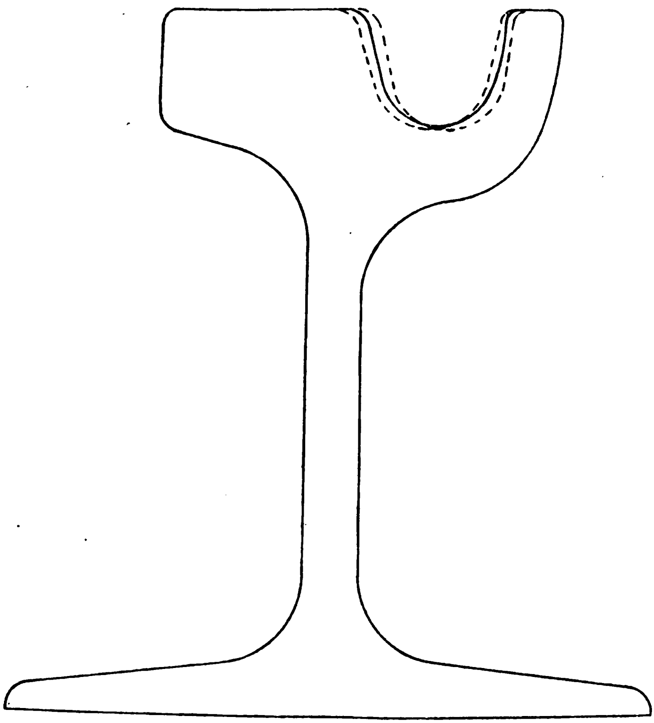


FIG. 8

groove. The latter sometimes is displaced relatively to the rest of the section, as indicated by the dotted lines in Fig. 8 (the full lines showing the proper form of the

section). The result of this is, that while some of the rails are accurately rolled to section, others are too wide (or narrow) in the tread, so that when fished together the edges do not correspond. Occasionally this irregularity occurs at one end of a rail only, owing to the groove not being quite parallel with the axis of the rail.

Another fault to which tramway rails are subject is defective width of the flange at one side; this is, however, of minor importance, as such rails are almost invariably bedded on concrete or ballast throughout their whole length. Particular care should be taken to see that the groove is not *too shallow* in tramway rails, and for the purpose of checking this a special gauge should be provided by the contractors. In addition to faults in the head common to other rails, tramway rails are also of course liable to cracks, flaws, scabs, &c., in the groove, more especially in the lip; the most usual defect being a longitudinal crack in the latter.

Tramway rails of the girder type are, as a rule, punched with oblong or oval holes for connecting tiebars; the inspector must see that the distance between these is correct. As made for English tramways there is usually plenty of clearance, and if the pitch of the tiebar holes is accurate, within say $\frac{1}{4}$ in., it is sufficient for all practical purposes.

The following forms the author has found to be convenient for recording the results of tensile and drop tests; they are self-explanatory :—

No...........................

REPORT OF TESTS

made on....................................*Rails, weighing* { ....*lb. per yard* / ....*kilos per mètre.*

manufactured at..

for account of..

BY

Bearings for Ball Tests...............*ft.* ....*for Lever Test*.........................*ft.* ....

No. of Pieces	Description	Falling weight, weighing					Dead pressure				Remarks
		ft.	ft.	ft.	ft.	ft.	tons	tons	tons	tons	
		Deflection					Defltn.	Set	Defltn.	Set	
Mean deflection and set											

Tests on fastenings, &c.

....

No...........................

REPORT ON TENSILE TESTS MADE BY

....

on samples of.................................*taken from*.................................*manufactured*

for Account of..*by*..

SPECIFIED TESTS.. 189

189	No. and mark on Test-piece	Dimensions in inches				Elastic limit in	Breaking load in	Breaking stress in tons per sq. in.	Elongation in per cent.	Contraction of area per cent.	Remarks
		Original		At fracture							
		in.	area	in.	area						

Hardness of Steel.—For tramway rails, especially those intended for use on steam or electrical tramways, the most important qualification is hardness and density.

For steels manufactured by a given process at the same works, the tensile strength may be taken as a measure of the hardness; but two steels having the same tensile strength may at the same time show very different results as regards wear and tear, and this is due to the difference in density or closeness of grain. This latter quality is attained by a suitable chemical composition, and can to some extent be checked by treating polished surfaces of the material with diluted hydrochloric or nitric acid; this makes irregularities in the grain apparent to the naked eye.

Some engineers attach such exclusive importance to hardness for tramway rails, that they consider elongation and deflection under a drop test to be unessential and specify only a very high tensile strength. This the author considers to be going too far. Although tramway rails are supported continuously, being bedded on concrete or ballast, there is always the probability of the latter being irregularly distributed or giving way in places under the load of passing cars. In that case the rails will be liable to deflection and consequent bending stresses.

Besides this, the rails must be capable of being bent, without detriment, to the required curves. It is there-

fore desirable that tramway rails should be subjected to some bending test, not too severe; for instance, a vertical deflection of, say, 1 in. in 3 ft., produced by steady pressure, and curving laterally to a small radius, say, 25 ft., first in one direction and then in the opposite, without sign of fracture.

SPECIFICATION OF RAILS AND FISHPLATES

1. **General Conditions.**—This contract comprehends the manufacture and delivery of the materials herein specified, in accordance with all the conditions of this specification and with the contract drawings.

2. The contract is to be executed in the most approved and substantial and workmanlike manner, and to the satisfaction of the inspecting engineer, who shall have full power and every facility for inspection, either in person or by deputy, during the progress of the work and the power to reject anything he may deem imperfect, either in materials or workmanship.

3. **Decision of Engineer Binding.**—The decision of the engineer upon any dispute or difference which may arise in connection with the contract, shall be final and conclusive.

4. **Approved.**—Wherever the word 'approved' occurs in this specification, it is to be read 'approved by the engineer.'

5. **Notice to Engineer as to Inspection.**—The manufacturer shall give to the inspecting engineer at least three clear days' notice before each commencement to manufacture, in order that an inspector may be present. Any departure from the conditions of this specification, refusal to allow sufficient inspection, or the carrying on of the manufacture in the absence of the inspector without due notice as hereinbefore provided, will render the materials with regard to which such irregularities occur, liable to rejection.

6. **Templates, Gauges, &c.**—The manufacturer shall prepare and submit for the approval of the engineer, before the manufacture is commenced, electram templates, male and female, engraved as may be directed in duplicate of the materials, together with a sample joint in strict accordance with which, when approved, the contract is to be carried out. The manufacturer is to pay the cost of all templates, gauges, all royalties (if any), and the carriage of samples, and is also to provide at his own cost, proper testing machines to the satisfaction of the engineer, and all labour or assistance, tools, or articles, which the inspector appointed by the engineer may require for the purpose of testing, gauging, or inspection; and also shall pay the expenses attendant upon any tests or analyses which the engineer may order.

7. **Contract not to be Sublet.**—No part of this contract is to be assigned or sublet, neither is any por-

tion of the work to be done in other than the contractor's own establishment, without the express consent of the engineer in writing being obtained first. All steel or iron used must be of the make named in the tender, or other approved make.

8. **Engineer's Certificate of Completion.**—Until the engineer shall have given his certificate in writing that the work is satisfactory to him, no portion thereof will be considered as being accepted, and should any defect be discovered even after it has been so certified it shall be liable to rejection at any time before the vessel in which it is shipped shall have actually sailed.

9. **Manufacturer to replace Damaged Work.**—The manufacturer will be required to make good and replace at his own costs and charges any portion of the work that may be broken or damaged either in the carriage or delivery, or in any way previous to its being shipped.

10. **Place of Delivery.**—The materials are to be delivered undamaged and in perfect order, free on board ship at   , in shipments as already arranged.

RAILS

Section and Weight.—The rails are to be of Vignoles' section, as shown on the drawing, and they are to exactly correspond with the template approved by the engineer. The weight of the rail is to be 60 lb. per yard; none will be received which weigh less than

$59\frac{1}{2}$ lb. per yard, and no allowance will be made for any over 60 lb. per yard.

Quantity.—The quantity of rails required is tons, equal to miles of single line.

Lengths.—At least 95 per cent. of the rails are to be in lengths of 30 ft., but a proportion not exceeding 5 per cent. will be accepted in lengths of 27 ft. and 24 ft., cut from longer rails which may be found faulty at ends.

Rails $2\frac{1}{2}$ in. shorter than the normal lengths are required for curves to the extent of about 10 per cent. of the above quantities. These must be painted white at each end. No deviation of more than $\frac{3}{16}$ in. from the proper lengths of the rails will be allowed.

Manufacture.—The rails are to be manufactured from solid ingots of Bessemer cast steel, of the very best quality manufactured for rails.

They are to be straight, free from cracks, burrs, or other flaws, and of uniform section throughout.

They are to show, when broken, a clean, close, and homogeneous fracture. Their ends are to be sawn off perfectly square. The ingots are to be cast of such a length as to leave a crop at each end of the rail of at least 1 ft. 6 in. to be cut off. All ingots are to be re-heated after cogging, unless otherwise approved by the engineer.

For the purpose of testing the quality, two pieces of rail 5 ft. long will be taken from each day's make, and

placed on solid bearings 3 ft. 6 in. apart, and in order that the rails of that day's make may pass, three samples shall stand the following tests, with a weight of 10 cwt. falling in proper guides:

1st blow, fall 20 ft. . . .	deflection not to exceed $2\frac{1}{2}$ in.
2nd blow, fall 20 ft. . . .	,, ,, $4\frac{1}{2}$ in.
3rd blow, with rail reversed, fall 20 ft.	deflection to be reduced to 2 in.

Rails not to be cracked or fractured.

The rails are also to be tested with a dead weight, as the engineer may require.

Analysis.—The chemical proportions in the ingots shall conform to the following:

The quantity of carbon to be from ·3 to ·45 per cent.
,, phosphorus not to be more than ·06 per cent.
,, sulphur ,, ,, ·06 ,,

The only metals shall be iron and manganese.

Punching.—Two oval holes, 1 in. by $\frac{7}{8}$ in., are to be drilled in the vertical web of the rail at each end, so that their horizontal centre line may correspond with the centre line of the fishplate. All holes must be clean, free from burrs or cracks, and square through the rails. Any deviation exceeding $\frac{1}{32}$ in. from the correct sizes and positions of these holes as shown on the drawing, will render the rails liable to rejection.

Marks.—Each rail is to have rolled distinctly on its side the name of the manufacturer, the words 'steel, 60 lb.,' the year of manufacture, and the letters A. B. R.

PIECES OF DEFECTIVE RAILS WITH FAULTS ON FLANGES

PIECES OF DEFECTIVE RAILS WITH FAULTS ON HEADS

FISHPLATES

Quantity.—The quantity of fishplates required is pairs. They will weigh lb. per pair completed.

Length and Section.—The fishplates are to be long and of a section exactly corresponding with the template approved by the engineer, and of the dimensions shown on the annexed drawing.

Manufacture.—They are to be rolled from Bessemer steel, but softer and tougher than that specified for the rails, and must be capable, when cold, of being bent double round a bar 4 in. in diameter, until the ends touch, without cracking or fracture; the tensile strength of the steel to be from 26 to 30 tons per square inch.

They must be cut square at the ends, must be perfectly straight and smooth on every surface, free from twists, burrs, or projections, and of uniform section throughout, and each fishplate must have four oval holes punched in it, of the dimensions and in the exact position shown on the drawing. Any fishplate showing signs of cracking or starring will be rejected.

Marking.—The letters A. B. R. and the year of manufacture are to be stamped or rolled on every fishplate.

Oiling and Packing.—After completion, the fishplates are to be dipped while hot into a tank of fresh, well-boiled linseed oil or other approved composition, and wired up in bundles to contain ten fishplates each.

The wire used to be $\frac{3}{8}$ in. thick and put on hot.

CHAPTER III

SLEEPERS

Prevailing systems of sleepers—Tests—Gauge—Coating and painting—Section and dimensions—Order and method of inspection —Templates—Weight—Fastenings.

In the British Colonies, India, on the Continent of Europe, and in South America steel sleepers are very largely used on railways, while in England timber sleepers are almost universal.

The system of sleeper adopted on the Continent is furnished with loose clips and bolts for holding down the rails, while in the Colonies, India, and South America sleepers with punched-up clips—forming part of the sleeper—and steel keys or wedges as fastenings have been found best adapted to the prevailing conditions.

For light lines a sleeper with riveted clips on the outside and loose clips held down by bolts on the inside is much in vogue. Except for very light work, sleepers are now always made with the ends bent over. Such sleepers are either pressed out of flat plates cut to the

required length, or else a trough-shaped or channel girder of approximately the specified section is rolled, cut into lengths, and each length pressed while hot into the final shape. The punching of the holes or punching up of clips in sleepers should be performed when the latter are cold to insure accuracy of gauge.

At the end of the present chapter an example of a specification for sleepers will be found.

Tests.—The tests specified for sleepers are generally of two kinds: hammer or cold bending tests, and tensile tests.

When the sleepers are rolled before being pressed, the test-pieces may be taken from the material before pressing, suitable lengths being cut off from the rolled trough-shaped girders from which the finished sleepers are formed.

Selection of Test-pieces.—The selection of test-pieces takes place much in the same way as for rails, but as the number made out of each charge or blow is much larger than in the case of rails, the number of test-pieces is generally proportionately less. From one to two tensile tests per thousand sleepers are generally required, but for the hammer tests more may be taken without inconvenience, as they are very easily carried out.

If the inspector is present during the whole period of manufacture, he can arrange matters so that his test-pieces are taken at regular intervals from different charges as the material is rolled. This is a much more

rational method than that of selecting test-pieces at random from finished sleepers, since in that case it may happen that two tests are taken from the same charge.

Tensile Tests.—For the tensile tests, flat bars about $1\frac{1}{2}$ in. wide are cut out of the top of the sleeper.

As a rule, material is required having a tensile strength of from 26 to 30 tons per square inch with an elongation of 20 per cent. in 8 in. Occasionally both elongation and contraction are prescribed, while sometimes only the latter is specified in addition to the ultimate strength. The contraction is usually 40 per cent. as minimum.

Tensile tests of flat bars—such as are cut from sleepers—involve somewhat more work than is necessary with round bars, as both the width and thickness have to be measured and the sectional area calculated instead of being taken from a table. The same remark applies to the measurement of the contracted area after fracture.

An accurate determination of the contraction of flat test-pieces is difficult owing to the varying thickness of the fractured section. If the results are generally well over the specified minimum, it is sufficient to measure the thickness at two points half-way between the middle and either edge and take the mean. Under all circumstances it is desirable to make sure of being on the safe side with the results; that is, that the calculated result is rather under than over the true value.

When the results are very near the specified limit, then the contracted section should be more carefully measured, the thickness being observed at several equidistant and equally distributed points.

A flat bar always breaks in such a manner that after fracture the corresponding points of the separated parts along the line of fracture are further apart in the middle than at the ends, so that when the two extreme ends of the broken section of each part are brought together there is a gap in the middle. It might be supposed from this that the elongation in the middle is greater than at the edges; but the author has found that this is not the case, and that the elongation measured along the centre line between the two edges is practically the mean of the elongations at the latter; at any rate, it is sufficiently near for practical purposes.

Bending or Hammer Tests.—It is usually specified that the material used for steel sleepers must stand bending double round a certain maximum radius *cold* without signs of fracture, and it is often stated that this is to be done by hydraulic pressure. As the latter is a slow process, manufacturers who are sure of their material generally allow the tests to be carried out with the steam-hammer, which is much quicker and at the same time more severe in its treatment than the press. A very slight local defect is sufficient to cause fracture under the steam-hammer; in such cases a second test

from the same piece—from one of the broken halves —frequently proves quite satisfactory; this shows that the material itself is not in fault.

The hammer test consists in first hammering a sleeper out flat *cold* under the steam-hammer and then bending it double in a longitudinal direction, backwards, to a radius of twice the thickness of the plate (or in some instances quite flat), also under the steam-hammer, but occasionally under a press. The material should stand this treatment without showing any sign of fracture.

Gauge.—The most important point in the construction of sleepers is accuracy of gauge, or, more strictly speaking, accuracy of those dimensions which determine the gauge of the rails to which the sleepers are connected. When inspecting sleepers, therefore, the gauge is the first thing which the engineer should check. In the steel sleepers generally in use on the continent of Europe the gauge can be easily checked for each sleeper separately, as it is dependent only on two rectangular or square holes punched in the top of the sleeper. In all there are four holes in the top of each sleeper for receiving the bolts by means of which the clips securing the rails to the sleepers are held down; the two outside holes, however, determine the gauge, while the distance from each of the latter to the nearest inside hole is fixed by the width of the rail flange.

Sleeper Gauge Template.—Templates for checking

both the gauge and the distance between outside and inside holes must be provided by the manufacturers. The first of these consists of a flat bar with a handle at each end, to which are firmly attached two rectangular dies which fit easily into the two outside holes. This is shown in Fig. 9. The distance from outside to outside of the dies should be *exactly* that required to give the specified gauge; the dies themselves may be a shade, say a full $\frac{1}{64}$ in., smaller than the holes in each direction. Often the distance between the holes is given without any intimation as to the section of the rails to be employed or the gauge. In this case the inspector cannot practically test the gauge, but must work to the dimensions given without first checking their accuracy. The author, however, considers it preferable always to try the gauge—if possible, with several sleepers—before proceeding to check the punching of each sleeper individually.

With sleepers furnished with punched-up lugs (of the pattern much used on the Indian railways) or having clips riveted on, it is impossible to test the gauge of *every* sleeper, as the gauge can only be checked by fastening the sleepers together with rails of the proper section, and this would occupy too much time if carried out with all the sleepers.

The gauge should, of course, be as accurate as possible, but must *on no account* be *less* than specified. For sleepers with punched-up lugs a margin of $\frac{1}{8}$ in. *over*

the specified gauge is usually considered admissible, and, generally speaking, it is preferable to keep the gauge slightly wide, rather than run the risk of its being too narrow in places.

On curves the gauge is always above the normal width, and sleepers are generally provided with some means of adjustment for widening the gauge; for instance, by means of bolts with eccentric square necks.

Coating and Painting.—Steel sleepers intended for transport by sea are almost always coated when hot with a mixture of tar and oil. This is effected by plunging the sleeper when hot into a bath of the coating composition, which is also hot. In this manner a smooth uniform layer of the composition is deposited on the surface of the sleeper. This layer should adhere so closely, and be so tough, that it is not easily knocked or rubbed off. Boiled linseed oil is sometimes used instead of tar and oil.

Light sleepers are occasionally painted with oil-paint.

Section and Thickness.—Before proceeding to inspect in bulk, the inspector should satisfy himself that all the dimensions of the sleepers are to specification. For this purpose he selects a sleeper at random and measures it carefully. In order to try the cross-section, it should be sawn across in several places, and tested by templates of the prescribed form. One of the

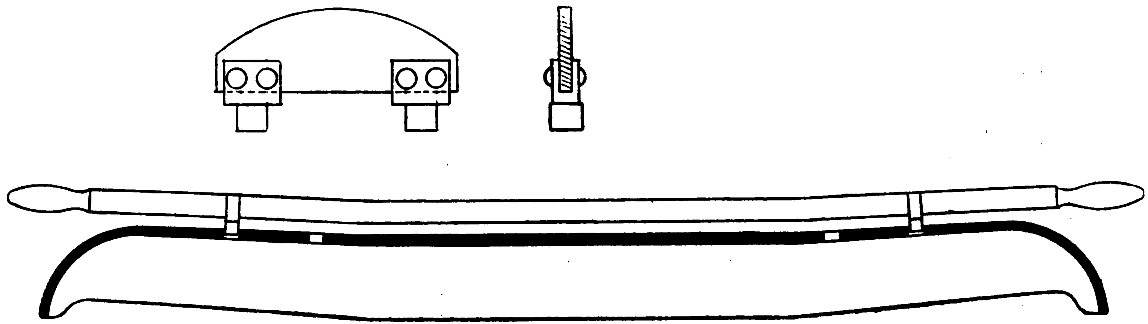


Fig. 9

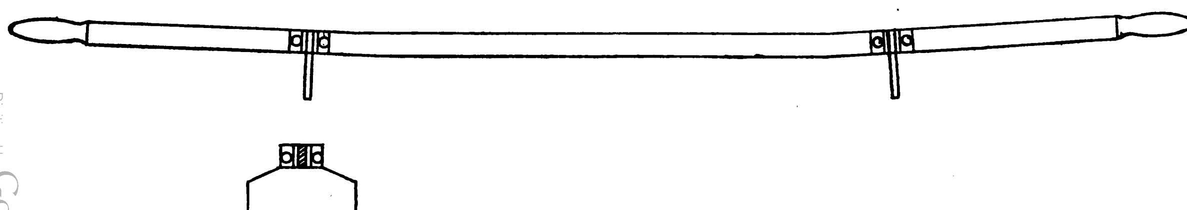


Fig. 10

most important dimensions is the thickness of the sleeper under the rail-seat. Some kinds of steel sleepers are furnished with loose bearing-plates, which grip the sleeper with projecting clips or hooks passing through rectangular holes in the latter. If the thickness of the sleeper at this point is too great, the bearing-plate will not fit, and cannot be got into position. On the other hand, if the sleeper is too thin, it will not wear so long.

Having satisfied himself that the dimensions are correct, the inspector should weigh the sample sleeper and see that the specified dimensions agree with the specified weight. If this is so, then any variation in dimensions will show itself in the weight.

The thickness should be tried at intervals during the manufacture.

As regards the length over all, if this is correct to begin with, it cannot afterwards vary much; the same remark applies to the width and depth.

Order and Method of Inspection.—For the purpose of examination by the inspector, sleepers are laid out in rows in the same manner as rails; in the first instance with the tops uppermost. Two men, one on either side, carry and apply the punching template; two others—who follow—a template for ascertaining whether the surface of the sleeper at the rail-seats is true. Simultaneously the distance between the two bolt-holes at either end of each sleeper is checked. It is hardly necessary to test the latter dimension for every sleeper

(as the two holes at each end are punched simultaneously by dies secured to one rigid crosshead), but it involves practically so little extra trouble that it is better to do so.

The template for trying the surface of the sleepers (*vide* Fig. 10) consists of two rectangular steel plates attached transversely to a steel or iron bar with a handle at each end, at such a distance apart as to correspond with the distance between the rail-seats. The edges of the plates must be straight and parallel with each other, and when laid on the rail-seats of a sleeper should touch both the seats simultaneously along their whole length. If the template can be rocked when resting on a sleeper, it shows that the surfaces are askew, and such sleepers must be returned to the works for correction.

When the necessary inclination of the rails—generally 1 in 20—is obtained by giving the rail-seats of the sleepers the corresponding slope, the punching template (Fig. 9) is also combined with a template for checking this slope. When the punching and surfaces of a whole row of sleepers have been checked, the inspector walks along each side of the row, thus looking at every sleeper from each end, for the purpose of seeing that they are free from faults on the outer surface. This done, the sleepers are all turned over so as to expose the inner surfaces, and the process is repeated for the latter.

The most usual faults in steel sleepers are cracks

where the sleeper is bent over—at the sides and at the ends. Frequently also splits occur at the ends parallel with the surface. In sleepers with punched-up lugs cracks occur in the upper edges of the latter, and also at the bases where the lugs are bent upwards. Sleepers which have been unsymmetrically pressed are also frequently found.

Weight.—In specifications for sleepers the normal weight is usually prescribed, and a certain margin above and below this allowed. Generally, single sleepers may weigh 2 per cent. more or less than specified, while the average weight of the whole must not deviate by more than 1 per cent. from the specified weight.

The weight should be checked every day by weighing a number of sleepers at intervals.

For ascertaining the average weight of the total, in addition to weighings of individual sleepers, a considerable number, 50 to 100, may be weighed at a time.

The inspector should satisfy himself that the average weight as determined by him is as near the truth as possible. To secure this end it is not so important that the number of sleepers weighed should be large, as that the weighings should be systematically taken every day during the manufacture, so as to arrive at a fair average: 1 to 2 per cent. in the case of large quantities is enough. In the interests of the buyers the inspector should be careful that the average weight fixed is rather under than over the mark; the manufacturers

may be trusted to look after their own interests in the matter. Of course the weight determined has to be communicated to them.

SPECIFICATION OF STEEL SLEEPERS AND KEYS

Drawing.—The sleepers are to be of the exact form and dimensions shown on the drawing No. .

Quantity.—The quantities required are as follows:

No.		Estimated Weight. tons.
	Steel sleepers	
	,, keys	

Description.—On each sleeper there are to be two pairs of clips or jaws.

These are to be formed, as shown on the drawing, by punching upwards a portion of the body of the sleeper. The sleepers are to be made from plates or strips of unequal thickness rolled in lengths and cut into pieces of the required length.

Quality of Material.—The finished sleepers must be free from cracks, splits, flaws, surface-pitting, and defects of any kind. The steel must be equal to a tensional strain of between 26 and 31 tons per square inch, with a contraction of area at the point of fracture of not less than 40 per cent., and it must also be capable of being bent double cold without showing any signs of fracture.

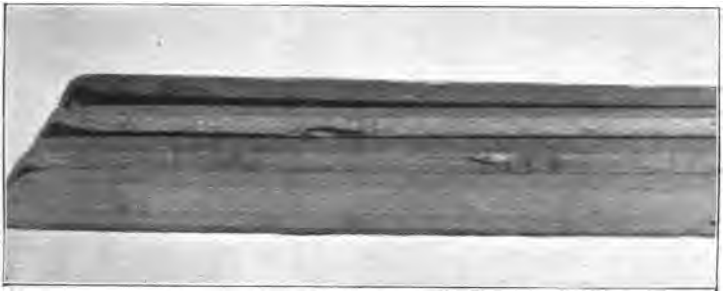
Construction.—The sleepers must be heated, and pressed or stamped into shape whilst red-hot, from plates measuring ft. long by in. wide, weighing nearly lb. per square foot.

The minimum thickness of the plates at the edges is to be in., increasing to in. at the centre. The dies are to be of such form that the rails shall have a tilt inwards of 1 in 20. All the jaws orclips of each sleeper are to be punched at one operation. All burrs round the holes are to be carefully dressed off and the plates well shaped. Each sleeper is to weigh not less than lbs. The total average weight shall not exceed this weight by more than 1 per cent., or under by 1 per cent. Any sleepers in which the jaws are not absolutely true to gauge will be rejected; the accuracy of the gauge is to be tested in the first instance, and periodically during manufacture, by laying down a 24-ft. length of road complete with sleepers, keys, and rails.

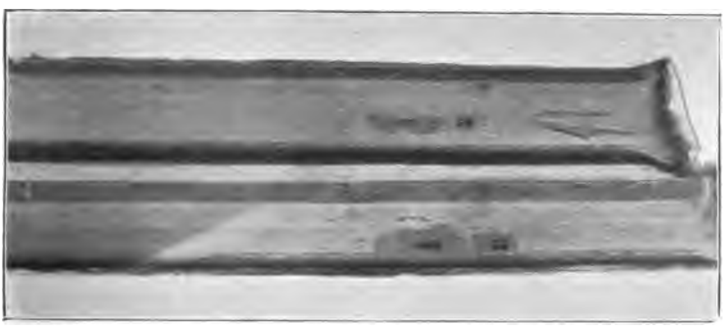
Keys.—The keys are to be of steel of the quality above specified. They are to be made in accordance with the drawing, and are to weigh lb. per pair. They are to be neatly finished and rounded off by means of grinding wheels, so as to easily enter the jaws of the sleepers.

Marks.—Each sleeper and key must be stamped with the initials A.B.R. and the year of manufacture.

Coating.—After being inspected and passed, the sleepers must be heated and dipped in a boiling solu-



DEFECTIVE SLEEPERS WITH FAULTS ON OUTSIDE



DEFECTIVE SLEEPERS WITH FAULTS ON INSIDE

tion composed of coal-tar and oil. The keys are to be dipped in boiling linseed oil, and when dry packed in strong close wooden boxes bound with hoop-iron, each case to contain about 5 cwt.

Sample Sets.—Three sets of specimen sleepers with keys, complete with pieces of rail, must be made and submitted to the Company's engineers for examination, and until the engineer shall have signified his approval of the same the remainder of the contract shall not be proceeded with. Such approval, however, is in no way to exonerate the contractor from any of the stipulations contained in this specification, or prevent the rejection of any sleepers of which the inspecting engineer may disapprove on any ground whatever.

CHAPTER IV

TYRES AND AXLES

TYRES: Specifications—Tests—Selection of test-pieces, &c.—Falling-weight tests and compression tests—'Drop' tests—Tensile tests—Dimensions, &c.—Diameter—Section—Gauges—Degrees of accuracy—Points requiring special attention—Weight—Faults—AXLES: Specifications—Tests—Gauges and measures—Method of inspection—Weight—Faults—Samples of specifications.

TYRES

TYRES are generally specified to be of Siemens-Martin openhearth steel. It is, however, generally practically impossible for an inspector to satisfy himself *absolutely* that this condition as to material has been complied with, unless the works supplying the steel manufacture openhearth steel *only*.

The best Bessemer or Basic steel, as regards tensile and impact tests, is equal in quality to the Siemens-Martin steel, and there is little doubt that the former is sometimes substituted for the latter.

Tyres should be rolled from *hammered* blocks with a hole punched—when the material is hot—in the centre, not from *cast* rings. This, of course, the inspector must check.

Tests.—Every tyre must have the number of the charge or 'blow' from which it is made stamped on its face. For testing, at least one tyre should be selected from every blow; where possible, tyres which have been rejected for defects which do not appreciably affect the strength may be taken for this purpose. After making the compression or falling-weight tests—to be subsequently described—with whole tyres, a piece is cut out from each test-tyre for tensile tests.

The tests usually specified are falling-weight (or compression) tests and tensile tests, but to these is sometimes added a so-called drop test.

Falling-weight Test.—The falling-weight test consists in placing the tyre in an upright position, resting on its rim, and subjecting it to repeated blows of a falling weight or steam-hammer until the inner diameter in the line of the blow is reduced by a given proportion of the original diameter; or, as it is often expressed, until the tyre is *compressed* to a specified extent without any sign of fracture being apparent. Usually the prescribed reduction in diameter is from 12 to 16 per cent.

Frequently only compression under an hydraulic press is required, while on the other hand, on the Continent, blows of a definite energy are specified, say, 3,000 kilogramme-mètres (or roughly 10 foot-tons).

During the test, the tyre must be so supported that the impact is distributed over the whole width of the

tyre and is not concentrated on the edge of the flange; for the same reason the falling weight must not touch the tyre itself, but is intercepted by a suitably formed block of steel placed on the top of the tyre. Before the commencement of the test and after each blow, the diameter is measured until the compression is sufficient.

Tensile Tests.—On account of the circular form of the rim, the pieces taken from the rims of tyres for tensile tests are generally shorter than the test-pieces cut from rails and sleepers. The elongation is, as a rule, measured on a length of from 2 to 3 ins. only (instead of 8 ins.); on the Continent, however, a test-length of 200 millimètres is specified.

A common test for tyres is a breaking strength of 35 tons per square inch, with an elongation of 25 per cent. in a length of 3 ins.; the diameter of the test-piece is from $\frac{3}{4}$ to 1 in.

On the Continent, for wagon- and tender-tyres, a softer steel of about 29 tons per square inch tensile strength is adopted; for locomotive tyres, a steel of 38 tons per square inch.

For exceptional purposes, tyres are sometimes ordered of very hard steel, say 50 to 57 tons per square inch tensile strength, with an elongation of 12 per cent. in 2 ins. With material of this kind, especial care should be taken to ensure the pull on the test-piece being central, otherwise a bending strain may be introduced, which detrimentally affects the results.

It may be noted that the tensile strength of pieces taken from the outer and thinner part of the rim is often greater than that of pieces taken from the thicker end or flange.

As in the case of rails, there is a tendency to increase the tensile strength of the steel used for tyres. A recent specification, which has come under the author's notice, prescribes a tensile strength of 45 tons per square inch, with an elongation of 12½ per cent. in 2 in.

'Drop' Tests.—In addition to the tests already described, it is occasionally specified that every tyre shall be dropped from a certain height in an upright position so as to fall with its rim on a steel rail or bar, and shall after this treatment show no appreciable permanent set.

Detail Inspection.—The first thing to be done when inspecting tyres is to ascertain that the cross-section of the rim is sufficiently correct. For the outer surface this is effected by means of a suitably shaped template (Fig. 11), and the other dimensions must be measured.

The width of the rim, if once correct, does not vary appreciably for different tyres of the same rolling; but variations always occur in the inside and outside diameters, and these affect the thickness. It is therefore necessary to check the inner diameter of every tyre, and to satisfy oneself that the rim is not too thin. It is not, as a rule, requisite to measure the outer

diameter of every tyre, but this should be done occasionally, especially where there is reason to suppose that a tyre is too thin. A certain admissible margin of error for the inside diameter is often specified; generally speaking, the diameter should not be more than $\frac{1}{16}$ in. larger than specified; and it is better that it

Fig. 11.

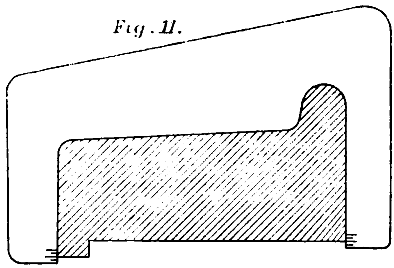


Fig. 12.

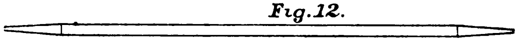
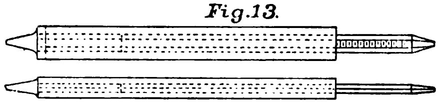


Fig. 13.



should be *less* rather than greater, since the inside of a tyre always has to be turned out to a fixed dimension. If the inside diameter is small, a little more metal can always be turned off, but if too large the quantity of metal left for turning may be insufficient.

Gauges.—For measuring the inside diameter, the author has generally used a plain round iron or steel rod (Fig. 12), of $\frac{5}{16}$ to $\frac{3}{8}$ in. diameter, tapered at the

ends, and cut and filed off to a length $\frac{1}{32}$ in. less than the required diameter. With this rod the inside diameter is tried, and it is easy to judge by eye whether the tyre is sufficiently true or not. If any tyre appears to be too large or too small in diameter, or not round, the dimensions should be accurately measured with a sliding gauge, such as that shown in Fig. 13. Tyres which are not round should be returned for readjustment if the inaccuracy is not great, but should not be re-heated.

Instead of gauging the outside diameter directly, it is a convenient plan to have the section template made so as to show the exact thickness of the rim (Fig. 11). When the inside diameter has been measured, the outside diameter can then be checked by applying the section-template.

The absolute value of the *outside* diameter of a tyre is generally not of so much importance as the inside; the main point is that the rim should not be too thin.

When examining for faults, it is important to see that the flanges of the tyres are rolled full, both as regards height and thickness; also that the tread of each tyre is truly conical and not round—as sometimes occurs.

It is convenient for the inspector to have each tyre rolled before him, with the inner face fronting him. He first checks the diameter and section, and examines the face and inside of the tyre for faults; the tyre is

then turned round, and the circumference and opposite face are inspected; the circumference of the tyre should also be scrutinised while it is being rolled into position, and rolled away again. The author has found it a good plan (in addition to the inspection above described) to walk along both sides of each row of tyres when they are stacked, for the purpose of a final examination of the circumference and flanges, more especially the latter.

AXLES

Axles for railway carriages and wagons are now usually made of Bessemer steel, and locomotive axles of either Bessemer or crucible cast steel. On the Continent, Basic steel is also much used for carriage and wagon axles.

Before finishing, while in the rough forged condition, a number of axles are selected from the bulk for testing.

It of course depends on circumstances whether the inspector has to examine the finished axles, or whether he has merely to inspect them as they leave the forge. In many cases axles are *not* turned and finished at the steel works where they are forged, and then the inspection and testing takes place at those works. For the purpose of testing, the contractors have to provide a certain percentage of additional axles, from 1 to 2 per cent.

Tests.—Tests for axles are of two kinds: falling-weight tests and tensile tests.

If possible, as in the case of tyres, a sample for testing should be selected from each charge (or blow) and every axle should have its charge number stamped upon it.

Falling-weight Tests.—The falling-weight test usually consists in placing the axle upon supports 3 ft. 6 in. apart, and subjecting it to repeated blows from a falling weight, the axle being turned through 180° after each blow, so that it is bent backwards and forwards in opposite directions. It must bear a specified number of blows without sign of fracture.

Sometimes the turning of the axle after each blow is not required.

In some Continental specifications, a given minimum deflection after a certain number of blows is prescribed; for instance, axles of 5 in. diameter are placed on supports 4 ft. 11 in. apart, and are subjected to repeated blows from a falling weight, having an energy of 10 foot-tons, until a deflection of 4 in. is attained without any sign of fracture.

An English specification for a well-known railway states that wagon axles are to be capable of standing without fracture three blows from a weight of 2,240 lb., falling from a height of 17 ft. 6 in. upon the axle, which shall be placed on bearings 3 ft. 6 in. apart. For the same railway, the axles of the composite passenger carriages are of the best Yorkshire iron double faggoted, and are required to stand the test of being

doubled cold without fracture; a similar test is also specified by another railway for *steel* carriage axles.

Tensile Tests.—When tensile tests are specified for wagon or carriage axles of steel, a breaking strength of from 32 to 35 tons per square inch, or thereabouts, with an elongation of 20 per cent. in 8 or 10 in., is usually required. As in the case of tyres, the pieces for the tensile tests can be cut from the axles used for the falling-weight tests after the latter have been carried out.

When axles have to be inspected before turning, it is, of course, of the first importance—as far as dimensions are concerned—that there should be everywhere a sufficient allowance of material for turning off; at the same time this should not be excessive. The diameter should therefore be carefully gauged all round at various points, and especially in places where an axle appears not to be quite circular.

For detail inspection, axles should be in rows, each marked with chalk at one point on the circumference, and rolled over slowly in succession, so that the whole surface can be carefully examined. The faults most easily overlooked are fine longitudinal splits on the surface. Where there appears to be such a split, the metal may be chipped away in order to ascertain how deep the fault penetrates. If it proves to be so shallow that it will entirely disappear with turning, the axle may be passed. The central portion of an axle between the wheel seats

is very frequently *not* turned, and should therefore be, if possible, more carefully forged and better finished than the other parts.

In order to ascertain whether axles are, before turning, sufficiently true and straight, each one should be rolled over, either on a line of rails or on a fairly level floor, while the inspector stands at some distance and looks along it. In this way any appreciable irregularity or want of straightness can be easily detected.

The following are samples of specifications :

SPECIFICATION FOR ENGINE AND TENDER TYRES

Falling-weight Test.—Any tyre in its rough state as it leaves the rolls (without being subsequently annealed or otherwise treated), when placed in a running position, on a solid foundation of at least 10 tons weight, and subjected to repeated blows from a tup of 20 cwt. falling from heights of 5 ft., 10 ft., 15 ft., 20 ft., 25 ft., and upwards, must stand a deflection of at least one-eighth of its inside diameter without showing any signs of fracture, except in the case of tyres under 3 ft. inside diameter, when a deflection of one-tenth of the diameter is sufficient. Very small tyres may be allowed a smaller proportional deflection than this.

Tensile Tests.—From each tyre with which the falling-weight test has been carried out, a test-piece of ½ square inch area and 2 in. effective length, machined

cold out of the solid portion of the rim, and not re-heated or otherwise manipulated, must show a tensile strength of from

51 to 55 tons per square inch,

and an elongation of not less than

10 per cent. in 2 in.

Process of Manufacture.—The steel employed must be made by the Siemens-Martin or acid open-hearth process.

The ingots are to be cast solid, and hammered on all sides. A solid piece of about 6 in. diameter must then be punched out of the forging, which is then to be further forged under the steam-hammer to the approximate section, and finished as usual in the rolls.

The finished tyres must be allowed to cool naturally in the air, under cover, and not annealed in any way.

Number of Tests.—A tyre for testing shall be taken from every 'blow' or 'cast,' and in no case less than 2 per cent. of the whole number.

Marking, &c.—Every tyre shall have clearly stamped on it the name of the manufacturer, the date of manufacture, and the number of the 'blow' or 'cast.'

SPECIFICATION FOR ENGINE AND TENDER AXLES (STRAIGHT)

Falling-weight Tests.—According to the diameter of the axles at the centre, the tests vary as follows:

Diameter of axle	Distance between bearings	Weight of tup	Height of fall	Number of blows
in.	ft. in.	cwt.	ft.	
6 and over	3 6	20	30	12
5 "	3 3	20	25	12
4 "	3 0	20	20	12

After every blow each axle is to be reversed, and when the test is completed must show no signs of fracture.

Tensile Tests.—Each test-bar to be ½ square inch area, cut cold from the axle, after it has been subjected to the falling-weight test, and without any re-heating or other manipulation to show a tensile strength of from 34 to 38 tons per square inch, with an elongation of 15 to 20 per cent. in a length of 2 in.

The steel employed to be made by the open-hearth acid process.

Number of Tests.—An axle for testing will be taken from each 'blow' or 'cast,' and in no case less than 2 per cent. of the order.

No. ....

REPORT ON FALLING-WEIGHT TEST OF TYRES MADE BY

....

on Tyres manufactured by ....

for account of ....

SPECIFIED TESTS 189

Date	No. and mark on tyre	No. of charge or 'blow'	Falling weight in lb.										Remarks
			Fall in feet =										
			Diameter before test	Diameters after each blow with Falling Weight								Total Compression	
			in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	

DEFECTIVE TYRES

CHAPTER V

RAIL FASTENINGS

Class of material and tests—Wrought-iron bolts—Steel bolts—Nuts —Spikes, soleplates, and clips—Rivets—Tiebars—Proportion of tests—Weight.

UNDER the heading 'Fastenings,' bolts, nuts, clips, spikes, rivets, and soleplates, &c., are generally included, and to these may be added tiebars for tramway rails.

BOLTS AND NUTS

Class of Material and Tests.—It is still very usual to manufacture bolts and nuts of wrought iron, although soft steel is now very extensively employed for the purpose.

Wrought-iron Bolts.—When wrought iron is used it should be of tough fibrous quality, must be capable of standing the test of bending double, when cold, round a bar of a diameter equal to that of the test-piece, and should have a tensile strength of at least 22 tons per square inch, with an elongation of 18 per cent. in 8 in.

In order to judge of the fibrous quality of the iron, a bolt or rod is nicked, and bent until partly broken through. It is hardly necessary to explain that 'nicking' consists in making an incision with a sharp chisel. When fractured in this way, the fibrous structure is clearly apparent. If a bolt or rod is fractured without nicking, the fracture has quite a different appearance, showing nothing of the fibrous structure. Another test, which is of a thoroughly practical character, since it corresponds with the treatment to which a bolt is actually subjected in practice, consists in screwing a nut on the bolt until it is locked against an opposing surface, and then, with a very long spanner, turning it until the bolt gives way. Good wrought-iron bolts of medium diameter will stand several turns of the nut before breaking.

Steel Bolts.—When bolts are of steel, the latter should have a tensile strength of from 23 to 27 tons per square inch, with an elongation of at least 22 per cent. in 8 in. The rods of which the bolts are made should, after being heated to a bright red, and quenched in water of 82° Fahrenheit, stand bending double round a diameter equal to half the diameter of the test-piece, without showing signs of fracture.

A piece of the bolt-rod, of a length equal to twice the diameter, should, when heated to a dull red, stand hammering down to one-third of its original length without showing any splits or other signs of fracture.

The twisting test may also be applied, as in the case of wrought-iron bolts.

Nuts.—The nuts should be of the same material as the bolts to which they belong.

Accuracy of Dimensions, Finish, &c.—Usually the outside diameter and length from inside of head to end of thread is specified for bolts, and in most cases the thread is cut to Whitworth's scale and gauges.

As regards the length, it is important that it should in no case be less than specified, so that when the nut (or nuts) are screwed home, the end of the bolt should not be below the top surface of the former. In the case of fish-bolts, the length should be such as to allow for possible variations in the thickness of the fish-plates, and for their being slightly wider than shown on the drawings, so that they cannot be forced quite so close up to the rail-web as is prescribed.

The threads should be cleanly cut, and each nut should fit so tightly that it can be screwed on by hand to about two-thirds of its depth; but beyond this only by means of a spanner.

This is a usual clause in English specifications.

The diameter of the bolts should not be less than specified; for the uncut portion of bolts that are not turned a certain + margin of from $\frac{1}{64}$ to $\frac{1}{32}$ in., according to size, can be allowed. If too thick it may happen that the bolts will not pass through the holes in the

rails and fishplates, although, generally, ample clearance is provided for.

Care should be taken to ascertain that the screwed portion of the bolts is long enough, more especially that the thread commences within the specified distance from the inside surface of the head. Very often the length of the screwed portion is given only from the *end* of the bolt, so that there is a possibility, if the latter is too long, that the thread does not approach sufficiently close to the head.

SPIKES, SOLEPLATES, AND CLIPS

Material for Spikes.—For spikes the same class of material as for the best bolts may be employed, with similar tests. It is of primary importance that the material should be tough, and stand any amount of hammering, and for this reason many engineers prefer wrought iron to steel.

Dimensions.—As regards dimensions, the point of chief importance is that the section of each spike should be sufficiently accurate, preferably of fully the specified section, but not too large to pass through the holes in the soleplates. In the author's opinion, a margin of $+\frac{1}{32}$ in. in the thickness and width of the spikes may be allowed; but these dimensions should not be more than $\frac{1}{64}$ in. less than specified.

Material for Soleplates.—For soleplates, soft steel of about 25 tons per square inch ultimate tensile

strength may be employed. The plates should stand bending cold through an angle of 45°.

Margins of Accuracy.—In the punching, a deviation of $\pm\frac{1}{32}$ in. in the distance between the holes, and $+\frac{1}{32}$ in. and $-\frac{1}{64}$ in. in the dimensions of the latter, may be considered admissible.

Material for Clips.—Clips should be of soft steel, with from 25 to 30 tons per square inch ultimate tensile strength, and an elongation of at least 18 per cent. in 8 in. After punching, the clips should stand bending cold through an angle of at least 45°.

When clips are inspected, they should be fitted together with one or more of the sleepers for which they are to be used, and two lengths of the corresponding rails. The bolts employed should, of course, be of the specified kind.

A similar remark applies to all the other kinds of fastenings; fishbolts, for instance, being tried with the fishplates and rails for which they are intended.

RIVETS

For rivets a very ductile material, capable of being worked when hot to any reasonable extent, is required.

When rivets are manufactured of wrought iron, the latter should have a tensile strength of from 22 to 24 tons per square inch, with a minimum elongation of 18 per cent. in 8 in.

The rods from which the rivets are made should

stand bending double when cold round a diameter equal to half the diameter of the rivet-rods, without showing any cracks.

A piece of rivet-iron, of a length equal to twice the diameter, when heated to a dull-red heat, should stand hammering down to one-third of its length, without splitting or showing other signs of fracture.

If soft steel is the material used for rivets, the tensile strength should lie between 22 and 26 tons per square inch, with an elongation of at least 22 per cent. in 8 in.

After heating to a bright red, and quenching in water of a temperature of 82° Fahrenheit, the rivet-rods should stand bending double round a diameter equal to half the diameter of the rod without showing any cracks.

The hammering-down test is the same as for wrought-iron rivets.

TIEBARS

Construction.—A tiebar for tramway rails—in England—generally consists of a flat bar, for example, 2 in. $\times$ $\frac{3}{8}$ in. in section, terminating in a bolt at one end, and furnished near the other end with two notches opposite each other. Into these notches the rail-web on one side must fit easily (as indicated in the sketch, Fig. 14), while the screwed end of the tiebar is made

fast to the web of the corresponding rail on the opposite side.

With this system of tiebar no great accuracy is required in the length, as there is plenty of scope for adjustment by means of nuts.

Clearance.—Care must, however, be exercised in forming the notches, as, on the one hand, they must allow sufficient clearance for the rail-webs, while, on the other hand, the clearance must not be excessive, as then the ties would not serve the purpose of keeping the gauge accurate. The width of the strip left between the notches must be such that the tiebar can be pushed through the oblong hole in the rail formed to receive it (shown in Fig. 15), while its wider surfaces are in a horizontal position, and then turned in the hole until the wider surfaces are vertical; it being, of course, assumed that the rails are in their proper position, with the webs vertical.

Other Types.—On the Continent the most usual form of tiebar consists of a simple flat bar flanged at either end, and having an oval hole in each flange. The length measured between the outside surfaces of the flanges must be such that when the ties are bolted up to the rail-webs the gauge is as nearly as possible accurate. Any deficiency is made up by the use of packing washers. In practice the ties are made rather shorter than is necessary to insure the exact gauge, so as to allow for adjustment by means of the washers.

In every case in which tiebars are inspected a few should be bolted up with two lengths of rail, and the gauge checked at various points.

If the gauge proves correct, one of the trial tiebars, of exactly the proper length, may be taken as a standard pattern, and the bulk checked with a special gauge which fits this pattern.

Another variety of tiebar consists of a flat bar with two pieces of angle-iron riveted to each end, each piece being of a length equal to the width of the bar. A hole

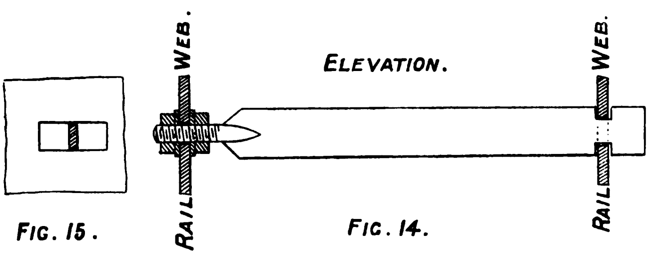


FIG. 15. FIG. 14.

is punched in each angle at either end of the tiebar; through each hole passes a bolt for connecting the rails. As regards gauge, the conditions are the same as for the tiebar previously described. It is important that the outer surfaces of the angle irons should be at right angles to the parallel edges of the flat bar, as well as to the broader surfaces of the latter. The distance between the two holes at either end must be accurate, within a small margin of error.

Material.—When of the pattern shown in Fig. 14,

tiebars are generally made of wrought-iron, which should be of good fibrous quality, as used for bolts.

In all other cases soft steel is generally employed. If tests are required, the author considers it sufficient that a bar should stand bending double round a cylinder of a diameter equal to twice the thickness of the bar. Very frequently no tests are specified.

Proportion of Tests for Fastenings.—The number of tests made from rail fastenings and rivet-rods is frequently left to the discretion of the inspector. If all the tests are satisfactory, the author considers that one test for every 4,000 pieces is sufficient. This seems, at first sight, a small ratio; but if, instead of comparing the number of tests with that of the fastenings (bolts, spikes, rivets, or soleplates), we base the former upon the quantity of rods or bars out of which the fastenings are formed, the matter assumes a different aspect, since, out of a single rod or bar, 50 to 100 fastenings may be formed. It is therefore preferable to state that from 1 to 2 per cent. of the rolled rods or bars from which the fastenings are manufactured should be tested.

Weight.—For determining the average weight of fastenings, 50 to 100 pieces may be weighed, selected so as to form a fair sample of the bulk. It is very generally specified—as in the case of rails—that the average weight is not to exceed 1 per cent. of that specified; in other instances a greater excess is permissible, but is not paid for.

CHAPTER VI

PLATES, FLATS, JOISTS, ANGLES, TEES, ETC.

Various applications and distinctions—Rolled material for bridges, roofs, &c.—Boiler plates—Ship-building material.

Classification.—Rolled material, such as plates, flat bars, joists, angles, tees, round bars, &c., may be classified, more especially as regards the tests, according to the purposes for which it is employed. Broadly speaking, it may be divided into three classes—namely, bridge material, boiler material, and shipbuilding material. Although the last mentioned does not come under the head of 'Railway Material,' the author proposes nevertheless to devote a few words to the subject.

BRIDGE MATERIAL

Iron or steel intended for use in the construction of bridges, roofs, and similar structures requires in some respects even more careful inspection than is necessary in the case of rails and sleepers. This applies more especially to the tests.

Excepting by a few of the older engineers, soft

steel is now almost exclusively used for the principal members of bridges and roofs, although for rivets, bolts, and nuts wrought iron is still much in vogue.

Tensile Tests.—Generally speaking, for bridge construction steel is employed having a tensile strength of from 24 to 30 tons per square inch and an elongation of at least 20 per cent. in 8 in. Sometimes a somewhat lower elongation is specified for tests in which the strain is at right angles to the direction of rolling—namely, 17 per cent. in 8 in.

Quenching and Bending Tests.—Bending tests are also invariably specified for bridge steel either with or without *quenching*. The quenching—if required—precedes the bending test, and consists in heating the test-piece to a 'cherry-red' heat, and then plunging it suddenly into water having a temperature of about 82° F. The piece must after this, when cold, stand bending double to an inner radius bearing some prescribed proportion to the thickness (frequently equal to the latter).

Drifting Test.—Sometimes, in addition to the tensile and bending tests, tests for 'red-shortness' are specified. Such a test consists in punching a round hole in a strip of the red-hot material, and enlarging it with a drift until the diameter of the hole is increased by 50 per cent., say from $\frac{3}{4}$ in. to $1\frac{1}{8}$ in. The metal must stand this treatment without showing any cracks.

Number of Tests.—In the case of steel intended for bridges and similar structures the number of tests required is much greater than in the case of steel rails or sleepers, owing to the difference in the conditions under which the two classes of material are manufactured and used.

When there is no definite specification as to the relative number of tests to be made, the inspector should make at least one test for every charge, and if all the tests are satisfactory this may be considered sufficient. A maximum proportion of 1 in 20 for the number of tests from each rolled section is frequently specified, in some cases one test for 2 tons of any given section.

If any test is not up to specification two new tests from the same charge or blow should be made, and if one of these is unsatisfactory the whole of the material rolled from the blow in question may be rejected.

Accuracy of Workmanship, &c.—When the specification contains no special provisions on these points, the following rules may be taken as a guide with regard to the admissible limits of accuracy:—

For *Flat Bars, Angles, Round and Square Bars*, a margin of $+ \frac{3}{4}$ in. is admissible in the lengths; an excess of weight up to 3 per cent. in the bulk and 5 per cent. in the case of single lengths; while no single length should be more than 2 per cent. under the specified weight.

For *Joists* a margin of + 1 in. in the lengths may be allowed, while for the weight the same rule can be adopted as for bars and angles. It may be noted that there are specifications which allow only $\frac{1}{4}$ in. margin of length.

In the dimensions of the cross sections deviations may be allowed of + $\frac{1}{32}$ in. and − $\frac{1}{64}$ in. for round and square bars; + $\frac{3}{64}$ in. and − $\frac{1}{32}$ in. in the width of angles; and + $\frac{3}{32}$ and − $\frac{1}{32}$ in the width of flat bars. In the thickness of bars and angles of medium section + $\frac{1}{32}$ in. may be considered an admissible margin provided the weight is within the specified limits.

For *Plates* the following rules may serve as a guide to the inspector :—

Widths	Difference between maximum and minimum thickness for Specified thickness		
	in. 0·2 to 0·28	in. 0·28 to 0·4	in. 0·4 and over
Up to 63 in.	$\frac{3}{64}$	$\frac{1}{32}$	$\frac{1}{32}$
From 63 to 70 ,,	$\frac{7}{100}$	$\frac{68}{1000}$	$\frac{68}{1000}$
,, 70 ,, 82 ,,	$\frac{8}{100}$	$\frac{7}{100}$	$\frac{7}{100}$
,, 82 ,, 106 ,,	—	—	$\frac{9}{100}$
,, 106 ,, 118 ,,	—	—	$\frac{12}{100}$

For widths over 82 in. and thickness up to 0·4 in. and also for widths over 118 in. these rules apply to the thinnest point.

For thin plates the following rules apply as regards weight and thickness:—

For thickness from 0·08 to 0·2 in.	± 5 per cent. margin	
„ „ 0·04 „ 0·08 „	± 7 „	„
„ „ 0·02 „ 0·04 „	± 9 „	„

Generally speaking, it is of chief importance that plates should not be thinner than specified.

The thickness should be measured at least $1\frac{1}{2}$ in. from the edge and 4 in. from the corners.

A deviation from the specified weight of 2 per cent. in the bulk may be allowed when not otherwise specified.

In the absence of a specification manufacturers generally claim for single plates a plus and minus margin of 5 per cent., but the author is of opinion that in framing a specification it is preferable to allow only a plus margin.

In so far as plates are used for bridge-building or general constructive purposes the tests are those already described.

For ship-building and boiler plates there are special provisions, which will be dealt with in the sequel.

BOILER MATERIAL

Boiler Plates.—The greater part of every locomotive, stationary, and marine boiler consists of either

wrought-iron or steel plates. Although the author is dealing primarily with railway material and is therefore mainly concerned with locomotive boilers, the class of plate used is practically the same as for the best boilers of other kinds.

Wrought-iron Plates: Tensile Tests.—When the plates are of *wrought iron* the latter should have a tensile breaking strength of from 20·5 to 22 tons per square inch with a minimum elongation of 15 to 18 per cent. in 8 in. *lengthwise*, and at least 19 tons per square inch tensile breaking strength *crosswise* with an elongation of 12 per cent. in 8 in. Plates intended for those portions which are exposed to the direct heat of the furnace—such, for instance, as the smoke tubes in a Lancashire or Cornish boiler—should have the greater elongation (18 per cent.).

Bending Tests.—Test-pieces cut lengthwise out of the plate must stand being bent double to a curve the inner radius of which is 1½ time the thickness without showing any signs of fracture.

Drifting Tests.—Holes drilled ⅝ in. diameter in the plates must stand drifting out to $\frac{15}{16}$ in. diameter before fracture commences.

Both bending and drifting tests must be carried out on the iron cold and unannealed.

Number of Tests.—One bending, drifting, and tensile test should be made from every plate, provided there are not more than two plates of the same thick-

ness in a boiler. A tensile test from every alternate plate is sufficient where there are more than two plates of equal thickness.

Steel Plates.—When boiler plates are of steel, the latter should be manufactured by the Siemens-Martin open-hearth process.

Tensile Tests.—For *boiler* and *fire-box shells* and dome-plates a steel should be employed having a tensile breaking strength of 26 to 30 tons per square inch with an elongation of 20 per cent. in 8 in. For inside fire-box and smoke-box tube plates the tensile strength should be somewhat lower, 24 to 28 tons per square inch with the same elongation.

Bending Tests.—In the case of steel, a test-piece, cut either lengthwise or crosswise from the plate, heated to a low cherry red and 'quenched' in water having a temperature of 82° F., must stand bending without signs of fracture, to a curve of which the inner radius is $1\frac{1}{2}$ times the thickness of the piece.

Drifting Tests.—After the test-piece has been heated and cooled as described, a drilled hole of $\frac{5}{8}$ in. diameter must stand drifting out to $1\frac{1}{8}$ in. diameter before fracture commences.

Forging and Punching Tests.—Sometimes, both for wrought iron and steel, the following further tests are required:

1. A strip of plate about 4 in. wide when red hot must stand being hammered out until the width is

increased by 50 per cent. without showing cracks on the surface or at the edges.

2. Holes punched in a strip of red-hot plate at a distance from the edge equal to half the thickness must not cause the strip to give way towards the edge.

SHIP-BUILDING MATERIAL

Iron or steel destined for the construction of ships is invariably subject to the rules of some society—such as Lloyd's. The following is an extract from Lloyd's rules for the quality and inspection of steel for shipbuilding:

Lloyds' Rules.—1. The steel will be required to withstand the whole of the following tests, to be applied at the steelworks under the personal inspection of the Society's surveyors, to samples selected by them from every charge or cast employed in the manufacture of the material, and these samples when marked by them for testing should be followed by the surveyors through the different stages of preparation until the tests are completed.

2. Every plate, beam, and angle shall be clearly and distinctly stamped by the manufacturer in two places where the brand cannot be conveniently sheared off after they have been tested, the brand to be similar to the following, thus: , denoting that a shearing

from the plate or angle so marked has successfully been bent cold, after being tempered as described in the temper test which follows, and that the plate or angle in question is capable of withstanding the whole of the tests hereafter described; and the Committee will require the surveyors, when in constant attendance at the steelworks, to satisfy themselves, so far as may be practicable, that these conditions are being complied with in a *bonâ-fide* manner.

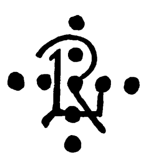
3. All plates, beams, and angles to be legibly stamped in two places with the manufacturer's name or trade-mark, and the place where made, which is also to be stated in the report of survey.

4. Should the samples selected by the surveyor not fulfil the test requirements, the plates or angles from which they were cut are to be rejected, and further tests are to be made before any material from the same charge can be accepted.

5. When one of the surveyors is not in constant attendance at the steelworks for the purpose of seeing the material tested, the Committee will require that tensile, and temper, and cold bend tests shall be applied, either at the steelworks or at the shipyard, to not less than one plate, angle bar, or bulb plate in every batch of 50, or a batch of less number; but the surveyor is not to select samples for testing until the material has been tested, stamped, and appropriated by the manufacturer. The sample when marked by the surveyor

for testing is to be followed by him when practicable through the different stages of preparation until the tests are completed. Should the samples tested not fulfil the test requirements, the whole of the material from the charge which produced the samples which fail to withstand the tests prescribed is to be rejected, or further tests are to be applied to a sample from each of the other charges of which the batch is composed. In the event of any of these samples also failing, the whole of the material from the same charge or charges is to be rejected as in the first instance.

6. Before these sample tests have been applied to a batch of steel submitted for check testing, the surveyor is to be furnished with a certificate by the manufacturer to the effect that the Society's requirements as to the testing of steel have been complied with in the case of the batch in question.

7. In the event of the material failing, in any case, to withstand the prescribed tests, the brands approved by the committee and stamped on the plates, beams, and angles by the manufacturer are to be defaced by punch-marks extending beyond the brand in the form of a cross, thus:  denoting that the material is rejected.

STEEL SUPPLIED IN INGOTS

8. Where steel is not produced in the steelworks at which it is rolled, a certificate is to be supplied to the surveyor testing the material, setting forth the name of the manufacturer who supplied it, the process of manufacture, and the numbers of the 'charges,' for reference to the books of the manufacturer if considered necessary, and the number of the 'charge' is to be marked on each plate or angle for the purpose of identification.

TESTS

9. Strips cut lengthwise or crosswise of the plate, angle, and bulb steel, to have an ultimate tensile strength of not less than 28, and not exceeding 32 tons per square inch of section, with an elongation equal to at least 20 per cent. on a length of 8 in. before fracture in samples $\frac{8}{20}$ in. and above in thickness, and 16 per cent. in samples below this thickness. Steel plates intended for garboard strakes, if specially marked for identification, may be tested to within the minimum limit allowed for boiler plates, viz. 26 tons tensile strength per square inch.

10. Steel angles intended for the framing of vessels and bulb steel for beams, may have a maximum tensile strength of 33 tons per square inch of section, provided they be capable of withstanding the bending tests, and of being efficiently welded.

11. Strips cut from the plate, angle, or bulb steel to be heated to a low cherry red, and cooled in water of 82° F., must stand bending double round a curve of which the diameter is not more than *three* times the thickness of the plates tested.

12. In addition to the temper tests required for *every* plate and angle, cold bend tests are to be made from each plate or bar tested for tension; also from all garboard plates, and all plates where it is known they are to be flanged.

13. In addition to this, samples of plates and bars should be subjected to cold bending tests at the discretion of the surveyors.

RIVETS

14. The steel used for rivets to be of special quality, soft and ductile, and samples of the rivets should be tested by being bent both hot and cold, by flattening down the heads, and by occasional forge tests, in order to satisfy the surveyors of their thorough efficiency.

TESTS FOR IRON

For iron plates for ship-construction Lloyd's Society lays down the following regulations:—

'With regard to iron to be used for ship-building purposes for vessels classed in this Society's Register Book, the same should be capable of withstanding the

test of 20 tons tensile strength with the grain, and 18 tons across the grain. In order to test its ductility, it should be capable of bending through the following angles *with* and *across* the grain, and a fairly good number of samples should be taken at the surveyor's discretion, to ensure that the whole of the material will withstand the tests set forth.

Thickness, in.	With grain, degrees	Across grain, degrees
1	10	—
$\frac{15}{16}$	10	—
$\frac{14}{16}$	15	—
$\frac{13}{16}$	15	—
$\frac{12}{16}$	$17\frac{1}{2}$	5
$\frac{11}{16}$	20	5
$\frac{10}{16}$	$22\frac{1}{2}$	$7\frac{1}{2}$
$\frac{9}{16}$	25	$7\frac{1}{2}$
$\frac{8}{16}$	30	10
$\frac{7}{16}$	$37\frac{1}{2}$	$12\frac{1}{2}$
$\frac{6}{16}$	45	15
$\frac{5}{16}$	55	$17\frac{1}{2}$
$\frac{4}{16}$	65	20

CHAPTER VII

CONSIDERATIONS GOVERNING THE FRAMING OF SPECIFICATIONS FOR STEEL RAILS

Conservatism of railway engineers—Diversity of tests—Treatment of rails—Load on rails—Bending test—Settling of ballast—Shocks—Fatigue—Woehler's law—Application of Woehler's law—Falling-weight test—Proposed new falling-weight test—Tensile strength as a measure of hardness—Density—Proportioning tests—Etching tests—Tensile test—Chemical composition—Fishplate steel—Effects of wear—Tests for hardness—Proposed specification.

In drawing up specifications for railway material there is a tendency on the part of engineers to run in certain grooves and copy each other's prescriptions without due regard to the special conditions of the case. On the other hand—more especially as regards tramway rails—the tests required for rails intended for use under practically identical conditions are absurdly different. One engineer, for instance, is satisfied with a falling-weight test which consists in a single blow of a tup weighing 1 ton from a height of 18 or 20 ft., while another requires three blows from a height of 20 ft., and that the rail shall be reversed before the third blow.

It will be best to consider ordinary rails and tramway rails separately, as the conditions under which they are employed are essentially different.

Treatment of Rails.—Let us consider the treatment to which, under ordinary circumstances, a rail (on a railway as distinguished from a tramway) is liable. In the first place, it has to act as a beam placed on supports (the sleepers) a certain distance apart, and subjected to a moving load passing over it at a high velocity.

As each rail is fastened down to a large number of sleepers—in the case of a rail 30 ft. long, about 12 sleepers—it might be looked upon as a continuous girder, except at the ends, where it is connected by fishplates to the adjacent rails. Here, however, are the weak points. In course of time the fishplates work themselves more or less loose, and, in order to be on the safe side, the rail must here be considered as a beam, free at one end and rigidly held at the other, with a load acting on the free end. The flexure is for this part of the rail contrary to that at other points between the sleepers, the head being in tension and the flange in compression.

Load on Rails.—Assuming the heaviest load on a locomotive wheel to be 10 tons, and the distance between the centres of the sleepers on either side of the joint to be 2 ft., the rail might from the static point of view here be treated as a short girder resting on

supports 2 ft. apart, and loaded in the centre by a weight of 20 tons applied against *the flange*. If we reduce this to the usual distance prescribed in specifications—namely, 3 ft. 6 in. or 3 ft.—we arrive at an equivalent load of 11·42 tons or 13·32 tons respectively.

Bending Test.—Hence, for heavy rails designed for main line traffic, we may lay down as a first condition that a piece of rail of about 5 ft. length, resting on its *head* on rigid supports 3 ft. 6 in. apart, shall be capable of sustaining a concentrated load in the centre between the supports for an indefinite time without showing any permanent set. In practice, five minutes is sufficient.

Settling of Ballast.—Owing to settling of the ballast, a rail may, however, occasionally be exposed to a much greater strain than is represented by the load above assumed, and in consequence have to sustain a stress in excess of the elastic limit; but the deflection resulting from the supposed settling can never in practice be great enough to produce a stress approximating to the ultimate strength, and on a well-kept track will not cause the elastic limit to be exceeded.

Shocks.—Setting aside for the moment the question of wear, the most severe treatment to which a rail is exposed results from the repeated shocks to which it is subject.

When a train in running over the track passes over some obstacle lying upon one of the rails, the latter

receives a blow, the energy of which is proportional to the heaviest load on any wheel, and to the height of the obstacle. Small stones may produce such shocks, and also inequalities in the height of the rail-tread at the joints. In a lateral sense also a rail is subject to shocks from the horizontal oscillation of the vehicles.

Effects of Fatigue.—Now, under normal conditions, no single shock is of sufficient magnitude to produce fracture, nor even a perceptible permanent deflection of any rail; but owing to the so-called *fatigue* of the material where such shocks are repeated a very great number of times, fracture may eventually occur. Two explanations of this fact are current.

Causes of Fatigue.—One of these is, that a gradual deterioration of the material, consisting in a change of its molecular structure, is set up by the continual shocks. The other explanation is based on the assumption that no material is perfectly elastic, and that consequently every deflection is in reality accompanied by a slight permanent set, which, when the strain is repeated, becomes cumulative, and eventually produces rupture.

Woehler's Law.—This result is embodied in what is known as Woehler's law, which is as follows:—'The fracture of any piece of material may be produced either by a single application of a load or by repeated applications of a much smaller load. In either case the work necessary to cause fracture is the same.'

Suppose, for instance, that a rail placed upon supports a certain distance apart is gradually loaded in the centre until it breaks under a maximum load, L, with the total deflection *d*. Denoting by L_m the mean load, the work required for this is

$$W = L_m \times d.$$

Then, according to Woehler, the same result may be produced by a smaller load, L_1, producing at each application only the deflection d_1, for which the work required is

$$W_1 = L'_m \times d_1,$$

where L'_m is the corresponding mean load. In each case the work required to produce the elastic deflection is $\frac{1}{2} L_e \times d_e$, hence the work expended in destroying the material is respectively

$$W' = L_m\, d - \tfrac{1}{2} L_e\, d_e,$$
$$W'' = L'_m\, d_1 - \tfrac{1}{2} L_e\, d_e,$$

where L_e denotes the load producing only the elastic deflection d_e.

The number of applications of the smaller load, L_1, required to produce fracture would be

$$n = \frac{W'}{W''}.$$

Application of Woehler's Law.—Assuming as before that the maximum concentrated load on a rail

is 10 tons, and that in consequence of some obstruction or irregularity at the rail joints this load now and then falls on a rail from a height of, say, $\frac{1}{4}$ in., then the energy, w_1, represented by each such blow is $\frac{1}{4}$ $10 = 2{\cdot}5$ inch-tons, or 0·208 foot-ton. If at each blow there is a very slight permanent set, then by repeating it a great number of times the rail would eventually be broken. Suppose the amount of energy at each blow absorbed in producing permanent set to be only one hundredth part of the whole, then this energy would be 0·002 foot-ton.

If a weight of 1 ton falling on a rail placed on supports 3 ft. apart from a height of, say, 40 ft. just suffices to produce fracture, then the number of blows required to produce the same result by a 10-ton weight with a fall of $\frac{1}{4}$ in. would be

$$n = \frac{40}{0{\cdot}002} = 20{,}000.$$

For the single blow from a height of 40 ft. the energy necessary to produce the elastic deflection is so small in proportion to the total energy that it may be ignored, otherwise it would have to be deducted from the latter before calculating the number of blows.

If the preceding arbitrary assumption were correct, the majority of rails would very soon be destroyed, so that we may be certain that 0·002 foot-ton is much over the mark. It is, however, clear that in principle

a falling-weight test is justified, and as a matter of practice very desirable, and to prove this is the object of the preceding calculation.

Falling-weight Test.—It may therefore be further laid down, as a general rule, that rails intended for use on ordinary railways (as distinguished from tramways) should be required to stand, without fracture, a fairly severe falling-weight test. The tests usually applied have been previously given. They consist in subjecting the rail, placed upon supports three or more feet apart, to several blows of a heavy weight falling from a considerable height.

Proposed New Falling-weight Test.—It occurred to the author that a more rational test would be that a rail should stand a very large number of blows from the same weight falling from only a small height, say $\frac{1}{4}$ to $\frac{1}{2}$ in., without, at the conclusion of the test, showing any permanent set. This would prove that, under repeated shocks of the most severe character to which a rail is likely to be subjected in practice, the material is not strained beyond the true elastic limit, or what for practical purposes may be taken as such. There would be no difficulty in arranging a machine to give automatically any desired number of blows from a given height. It may not be superfluous to remark that as long as the limit of elasticity is not exceeded—apart from subsidiary phenomena, such as heat or electricity—no energy is permanently transferred to the

material, since the whole energy represented by the blow is returned to the weight on the rebound of the rail.

It might be safely assumed that if a rail will stand, say, 1,000 blows without showing any measurable permanent set, the limit of elasticity has for practical purposes not been exceeded.

This test would be more in accordance with the scientific requirements of the case than the usual falling-weight test, and with a suitably designed apparatus need not occupy much more time than the latter. The apparatus would have to be furnished with an automatic counter for recording the number of blows, and when once adjusted could be left to do its work without continual superintendence.

With a view to obtaining an experimental basis for falling-weight tests conducted on the principle suggested, the author recently carried out some trials for the purpose of ascertaining what energy of impact a rail of a given section would stand without showing any permanent set.

The rail with which the trials were made was a flange rail, weighing about 67 lbs. per yard, about 5 ft. long. When placed on supports 1 mètre apart, this rail stood repeated blows from a weight of 1,000 kilogrammes, falling from a height above the top surface of the rail-head of 150 millimètres, without showing any permanent set. The deflection at each blow was about 9 millimètres.

A rail of the section in question, and of the same length, when gradually loaded with dead weights in the centre between supports, also 1 mètre apart, will deflect at most about 3 millimètres with a load of about 20,000 kilogrammes without permanent set. Hence we find that under a blow it will bear a deflection *three* times as great as under a 'dead' load without showing permanent set.

If we compare the energy expended on the rail in the two cases we find—

$$\text{for the blow: energy} = 1{,}000 \times 159 = 159{,}000;$$

$$\text{for dead load: energy} = \tfrac{1}{2}20{,}000 \times 3 = 30{,}000;$$

which gives a ratio of 5·3 : 1.

This curious result explains the frequently observed fact that rails which, when subjected to tensile tests, show comparatively little elongation, stand the falling-weight tests in a perfectly satisfactory manner, as well as rails with a much higher percentage of elongation.

From this it seems clear that the internal strains occurring when deflection is caused by impact are of quite a different character from those produced by deflection under a dead load.

It is a question whether the elastic deflection under impact depends solely on the energy of the blow, or whether it varies with a varying proportion of weight to height of fall.

Experience shows that the permanent set depends

practically only on the total energy of impact, whether this be obtained by one blow from a given height, or by several blows from a smaller height. In practice, however, falling-weight tests are generally made with blows from a considerable height with a load not over 1 ton, so that it would not be safe to apply the conclusions thus arrived at to much heavier weights and much lower falls, and to cases where only the elastic deflection is in question.

It will throw some further light on the subject if we consider briefly the theoretical conditions of the problem —that is, the conditions which would apply if the strains produced were of the same kind for both impact and dead load.

Let L denote the gradually applied load necessary to strain a rail resting on supports, as previously assumed, to the elastic limit, and producing the deflection, *d*. Further, let G be the weight falling from the height, *h*, above the rail, which will produce the same deflection, *d*.

Then the equation should hold good:

$$\tfrac{1}{2}\,\mathrm{L}\,d = \mathrm{G}\ (h + d)\,;$$

whence $$h = \tfrac{1}{2}\frac{\mathrm{L}}{\mathrm{G}}\,d - d \;=\; d\left(\tfrac{1}{2}\,\frac{\mathrm{L}}{\mathrm{G}} - 1\right).$$

It is evident from the above formula that with a given deflection there is a limit to the value of G, for which $h = 0$. When this limit is reached there is no

longer any impact, but we have the case of a load suddenly applied. This occurs, for $G = \frac{1}{2} L$; that is to say, a weight suddenly applied is equivalent in its action to *twice* that weight gradually applied, a well-known law which can be deduced in another way.

Assuming the data previously given for the experimental rail:

$$L = 20{,}000 \text{ kilogrammes},$$
$$d = 3 \text{ millimètres},$$

further $$G = 1{,}000 \text{ kilogrammes},$$

then we should have

$$h = 3\left(\frac{1}{2}\,\frac{20{,}000}{1{,}000} - 1\right) = 27 \text{ mm}.$$

As a matter of fact, h has more than $5\frac{1}{2}$ times the above value.

For $G = 10{,}000$, $h = 0$. That is, the greatest load which could be suddenly applied to the rail under the assumed conditions without producing permanent set would, according to the usual theory, be 10,000 kilogrammes. Experiments have shown that in practice the effect of a suddenly applied load relatively to that of gradual loading is not quite as great as theory indicates, but the discrepancy is small in comparison with that which has been shown to exist in the case of impact with a falling weight of 1,000 kilogrammes.

It seems therefore probable that with increasing weight the energy of impact required to strain the rail to its elastic limit approximates ever more closely to

that which theory would lead us to expect, until at last the point is reached at which there is no impact, but only a load suddenly applied.

In order to carry out the proposed tests consistently, it would be necessary to employ a falling weight equal to the greatest load on any wheel passing over the rails in question.

Effect of Train Velocity.—The foregoing considerations lead up to another demand which must be made upon the strength of rails. It has been shown that the effect of a sudden load is twice that of one gradually applied. When a train passes over rails at a high speed, the pressure exerted on these approximates more or less to a suddenly exerted load, although the effect of the latter can never be attained without impact. If, therefore, the maximum load on any rail is 10 tons, the same rail should, allowing a margin for safety, be capable of carrying *twice* that load, *gradually* applied, without permanent set.

The specification in this case would read: A short piece of rail placed on supports 3 feet apart must, when loaded in the middle between the supports with a weight of 26·66, or, say, 27 tons, show no permanent set.

With the newest type of fishplate, which grips the flange of the rail above and below on both sides of the web, the joint, if kept in good order, is as strong as the rail. In this case the conditions are obviously much more favourable, since the rails on either side of the

track may be considered throughout their whole length as a continuous girder. Looked at in this way, a load of 10 tons midway between two sleepers—say 2·5 ft. apart—would be equivalent to only five tons placed on the centre of a short piece of rail resting freely on supports placed at that same distance apart, or 4·17 tons with supports 3 ft. apart. Taking into account, as before, the effect of a sudden load, the piece of rail should, under the preceding assumptions, be able to bear a load of 8·34, say, 8·5 tons, without showing any permanent set.

Proportioning Tests.—The question has sometimes to be answered: If a rail of given section stands a certain falling-weight test, what test should be applied to a rail of some other section, made of the same class of steel, in order to produce the same stress with the same distance between the supports? For practical purposes it may be assumed that the energy of impact should be proportional to the moment of resistance, M, and inversely proportional to the distance, a, of the extreme fibre from the neutral axis—that is to say, the distance from the upper surface of the head or the under surface of the flange—whichever is greater—to the neutral axis. Supposing the neutral axis to pass through the centre of gravity of the section, then, as a rough approximation, the energy of impact may be taken as proportional to the weight per yard of the rail; but this rule can only be applied to rails of geometrically similar section.

For bending tests with a dead load, the loads necessary to produce the same stress with a given distance between the supports are proportional to the moments of resistance of the sections.

In order to enable the reader to form his own judgment on this subject, the falling-weight and bending tests required by various specifications are given in a tabular form in the sequel.

A further question is: How should the falling-weight test vary with the distance between the supports in order to produce the same maximum stress in rails of a given section? If, for example, with supports 3 ft. apart, the rail should stand the impact of a weight of 1 ton falling 20 ft., what ought the same rail to stand with the supports 3 ft. 6 in. apart?

At first sight it would appear as though the energy of impact should be *inversely* as the distance between the supports, but it is easy to prove that, on the contrary, the energy of impact is approximately *directly* proportional to that distance. Hence, if with a weight of 1 ton the fall (h) is 20 ft. for a distance between the supports, $l = 3$ ft., then for $l = 3$ ft. 6 in.,

$$h = \frac{3{\cdot}5}{3} 20 = 23{\cdot}33 \text{ ft.}$$

This rule would not be applicable for a very heavy weight falling through a small height where the deflection is very considerable in comparison with the fall. In ordinary cases, however, the opposite holds good,

and the deflection is practically negligeable in proportion to the fall. To be strictly correct, the deflection must be included in the fall.

For bending tests with a dead load the load should vary *inversely* as the distance between the supports.

SUMMARY OF VARIOUS FALLING-WEIGHT TESTS

Description of rails	Weight per yard	Falling weight	Fall [1]	Energy of impact	No. of blows	Remarks
	lbs.	tons	feet	ft.-tons		
Vignoles (Belgian Ry.) .	104·8	0·984	16·4	16·15	1	All calculated for supports 3 feet apart
Vignoles (Colonial Ry.) .	41	0·392	52·0	20·38	4	
" " "	50	0·500	42·0	21·00	4	
" " "	61	0·500	52·0	26·00	4	
Vignoles	40	0·492	32·8	16·14	1	
Bullheaded (English Ry.)	95	1·00	23·1	23·1	2	
" " "	86	1·00	21·0	21·0	2	
" " "	77·5	1·00	15·4	15·4	2	

SUMMARY OF VARIOUS BENDING TESTS

Description of rails	Weight per yard	Load in centre	Specified conditions	Maximum deflection	Remarks
	lbs.	tons			
Vignoles (Belgian)	104·8	41·2	No permanent set		All calculated for supports 3 feet apart
" "	76·6	25·98	" "		
Vignoles (Colonial) .	41	10	" "		
" "	50	12	" "		
" "	61	15	" "		
Vignoles . . .	40	10·75	" "	4 mm.	
Vignoles (German) [2]	67·3	21·4	" "	3 mm.	

[1] In most cases several blows from various heights are specified; under 'fall' the sum of these heights is to be understood.

[2] For the German railways no bending tests are specified, but the data given correspond with experiment.

Wearing Capacity.—Hitherto many engineers have considered the falling-weight test for rails to be the only test really necessary, and hold tensile tests superfluous. There are numerous specifications for important railways in which a falling-weight test only is required.

As far as the *strength* of the rails is concerned, this view is correct; but those who hold it leave out of consideration one very important factor influencing the life of rails—namely, their capacity to resist wear. In order to attain this capacity it is necessary to have a hard and, at the same time, dense and homogeneous material, especially in the head of the rail.

Tensile Strength as a Measure of Hardness.—Under otherwise similar conditions, the tensile strength is a measure of the hardness, and for this reason the author considers it desirable to make tensile tests of rail steel, and to specify for the latter a high tensile strength. The tensile strength is, however, only a *relative* test of the wearing capacity. It is quite possible to have two samples of steel showing exactly the same results when subjected to tensile tests, of which one will wear well and the other badly. This is due to the difference in density and homogeneity, more especially in the upper part of the head.

Density of Steel.—Whether the steel is dense or not depends on its composition and the method of its manufacture.

It may therefore be stated that for a given *make* of steel the tensile strength is a measure of its hardness.

Etching Tests.—There is besides the tensile test another method of investigation, which is capable of giving reliable information on this point. That is, etching by means of acid or other solution. A slice is cut from a rail at right angles to its length, one or both surfaces polished, and it is then subjected to the action of the acid or solution. If this is done in a suitable manner, the polished surfaces are so affected that they show all imperfections in the structure of the steel.

Tensile Test.—A tensile strength of 40 tons per square inch at least may be reasonably required for ordinary rails. There is no necessity to specify elongation if falling-weight tests are prescribed, and there is no object whatever, in the author's opinion, in requiring a particular amount of contraction.

Chemical Composition.—It is a mistake to specify the chemical composition of the steel to be used for rails. This should be left to the manufacturers. The engineer may be satisfied if he obtain material possessing all the mechanical qualities which he requires, and may in general safely entrust the methods of production to the makers.

The mechanical properties of steel—such as strength, resistance to impact, elasticity, hardness—depend, not merely on the proportion of carbon in the metal, nor even on the percentages of carbon and phosphorus, but

upon all the ingredients taken together; and similar results may be attained by different makers with different proportions of the various components.

For Bessemer steel and for Thomas-Gilchrist steel the methods of production and the proportions of carbon, phosphorus, sulphur, silicon, and manganese necessary to produce a given result are not identical.

Generally speaking, the percentage of carbon required for a given tensile strength is greater in basic (Thomas-Gilchrist) steel than in Bessemer steel, and the proportion of silicon is also different.

As a general rule, the amount of phosphorus should not exceed 0·06 per cent., and the same holds good for sulphur.

For Bessemer steel, such as is now employed for ordinary rails, the carbon ranges from 0·35 to 0·40 per cent., while for Thomas-Gilchrist steel 0·40 to 0·45 is nearer the mark.

Fishplate Steel.—For ordinary fishplates the quality of steel employed is usually softer than that of which the rails are made, in order that it may adjust itself more readily to the surfaces of the rails against which the fishplates abut. In the author's opinion this is not really necessary, as is proved by the fact that for tramway rails with so-called patent joints, where the top of the fishplate forms a portion of the surface on which the wheels of the vehicles run, both rails and fishplates are made of the same class of steel.

Effects of Wear.—As regards the effects of wear upon steel rails, some interesting experiments were recently made by Mr. William George Kirkaldy, the results of which are given in a paper [1] read by him before the Institution of Civil Engineers.

These experiments tend to show that in course of time the steel forming the heads of rails frequently suffers deterioration from the hardening, and eventually disintegrating, action produced by wear. This is chiefly apparent in rails on which the brake is often applied, or trains are continually started. In such rails the steel forming the head has become harder, but has a smaller ultimate tensile strength and less elongation than when new. Bending tests made on these rails with the load resting on the flange—the head being in tension—showed the resistance to be much less than when similarly tested in the normal position with the head in compression, although in new rails there is little difference in the results, whether the bending test be made in the usual or the inverted position. It must be remarked that Mr. Kirkaldy does not take the ultimate tensile stress as a measure of the hardness, but determines the latter by a test under thrusting stress of a cylinder 1 in. high, and of a diameter giving an area of 1 square in. In every case in which deterioration was proved, the head of the rail showed

[1] *Minutes of Proceedings of The Institution of Civil Engineers*, vol. cxxxvi., Session 1898–99, part ii.

what Mr. Kirkaldy terms an *induced* flaw. Generally speaking, Mr. Kirkaldy's tests tend to show that when not subject to frequent brake or similar action the quality of rail steel is not appreciably affected by long use. Many of the rails tested had been subject to heavy traffic for periods varying from seventeen to twenty-three years.

Tests for Hardness.—It has been previously mentioned that the ultimate tensile strength of steel is very generally taken as a measure of its hardness and consequent capacity to resist wear and tear. In the author's opinion some more direct and reliable test for hardness is required. Various methods of carrying out such a test have been proposed, and all resolve themselves into determining the resistance which the surface of the steel tested offers to depression.

Professor Unwin made experiments of this kind in which the indentation produced in the surface of tested material by the sharp edge of a loaded hard steel prism was accurately measured. At present similar trials are being carried out on behalf of one of the Continental State Railways, in which, however, instead of steel prisms hard steel balls are employed.

As already incidentally stated, Mr. W. G. Kirkaldy regards compression tests of cyclinders of the test-material, 1 in. diameter and 1 in. high, as a criterion of hardness.

From a practical point of view the last-mentioned

test would be the most convenient, as it admits of being easily and accurately carried out. On the other hand, the tests by means of prisms or balls—especially the latter—correspond more closely to the actual circumstances.

It has also been proposed to gauge the hardness of rail steel by its resistance to shearing or punching. This appears to the author a rational suggestion.

When the wheel of a locomotive or carriage rolls over a rail, both the surface of the tyre and that of the

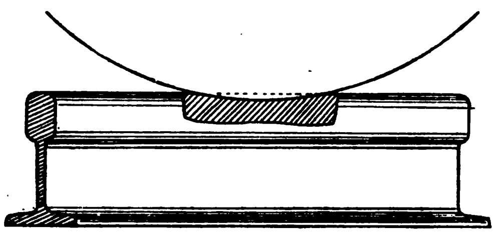


Fig. 16

rail are depressed, and it is clear, apart altogether from skidding action, that the greater the local depression, the greater must be the wear and tear.

The sketch (Fig. 16) will render this obvious, in which the contact between wheel and rail surface is shown greatly exaggerated. That part of the rail immediately below the surface of contact with the tyre is subject to local and unequal compression, and as the wheel rolls onwards every portion of the rail surface is successively

treated in this manner. The result is what may be termed a continual *kneading* of the steel. When skidding or slipping of locomotive wheels takes place matters are still worse.

The obvious deduction from this is, that the resistance of rail steel to local depression or compression should be as great as possible. If it were possible to obtain a steel which would not yield to compression, then, in the absence of skidding or slipping, there would be no wear.

Tests with knife-edges (of prisms) or balls, such as those referred to, have the drawback that in order to obtain reliable comparable results all tests must be made with prisms or balls of exactly the same dimensions and quality, or else a standard sample of steel of known character must always be at hand for comparison with those on trial.

In the author's opinion, compression tests on short cylinders, as described by Mr. Kirkaldy, would probably answer all purposes. The diameter of the cylinders could be exactly determined, and the pressure per unit of original sectional area required to produce a certain amount of compression then calculated in precisely the same manner as for tensile tests. If practically more convenient, the compression corresponding to a given constant pressure might be measured. The ratio (Pressure per unit of sectional area) : (Compression) would be a criterion of the hardness of the steel and of

its wearing capacity. The best steel for wearing purposes would be that showing least compression under a given stress. It would be preferable to keep the stresses caused by such tests within the elastic limit, if this could be done without involving measurements of too delicate a character for ordinary practical work.

It does not follow that among various steels that giving the best results would also have the highest tensile strength, but it seems probable that the tensile limit of elasticity would be high.

In connection with this subject some interesting particulars are given in a paper read at the General Meeting of the Austrian Society of Engineers and Architects, on March 26, 1898, by Von Dormus (Engineer of the Kaiser Ferdinands Nordbahn), and re-published, with an English translation, in 'Baumaterialienkunde,' commencing in No. 16 (1899). The whole of this essay may be read with advantage by those interested in the subject of rail steel, but the particulars now in question relate to the difference in the wear of rails of apparently exactly similar character.

On one portion of the Nordbahn a section, A, of about 1¼ mile long, required new rails after being in use only about eleven years. The rails were much worn, and frequently became fractured. In some cases as much as 0·366 inch was worn away.

On another section, B, on which rails of the same form and weight per yard were laid, and which was

subject to a heavier traffic, the maximum wear, after twenty years of service, was only 0·075 in., while in no instance did a fracture occur.

Both sets of rails had been tested in accordance with the same specification, and accepted as satisfactory; while falling-weight tests, bending tests, chemical analyses, and tests for hardness recently carried out, after the rails had been in use, showed no essential differences between the rails from the two sections, such differences as occurred being, however, in favour of the badly-worn rails from section A. A number of sections from each set of rails were cut, polished, and etched, and then only the cause for their different wearing capacity became apparent. There could, then, be no doubt that the bad behaviour of the rails from the A section was due to want of homogeneity, as demonstrated by the irregularity of the etched surfaces. The cuttings of rails from section B were uniformly attacked by the etching liquid over the whole surface.

It seems probable that in future the etching test will be very generally employed in addition to the methods of investigation hitherto in use; possibly it might with advantage replace one or more of the latter.

For rails intended for use in a temperate climate under heavy main-line traffic the author would suggest the following specification:

BODMER'S SPECIFICATION FOR STEEL RAILS

(*weighing, say,* 80 *lbs. per yard*)

Every rail must be stamped with the number of the 'blow' (or 'cast,' or 'charge') from which it is rolled.

The rails selected for testing are to be taken from different charges, approximately evenly distributed throughout the rolling.

On every rail selected for testing the following tests are to be made:—

Dead-weight Test.—A piece of rail not more than 5 ft. long, placed *flange upwards* upon supports 3 ft. apart from centre to centre, must, for at least five minutes, bear a dead weight of 27 tons, acting in the middle between the supports without showing any permanent set; and the deflection under the above-named load must not exceed $\frac{1}{8}$ in. Before commencing the test the rail must be loaded with a weight of 10 tons in the middle, in order to insure its being properly bedded on the supports.

Falling-weight Test.—A piece of rail about 5 ft. long, placed *head upwards* upon supports 3 ft. apart from centre to centre, must stand the following blows from a weight of 1 ton, falling upon the middle of the rail between the supports:—

(1) Twenty blows from a height of 6 in. above the top surface of the head without showing any permanent set.

(2) One blow from a height of 20 ft. without showing any signs of fracture.

Tensile Test.—A piece of steel cut cold out of the head of the rail and turned cylindrically to a diameter of not less than 0·8 in., with a test length of 8 in., to show a breaking strength of at least 42 tons per square inch of original area.

N.B.—In the author's opinion it is unnecessary to specify elongation, since, if the rails stand the falling-weight test and dead-weight test satisfactorily, all practical requirements which can be ascertained by mechanical tests are satisfied. Should it, however, be considered desirable to require a definite elongation, then Tetmayer's rule may be adopted, namely :—The product of the tensile breaking strength expressed in tons per square inch, and the elongation (in a length of 8 in.), expressed in percentage, must equal at least 571·45. This gives for 42 tons per square inch an elongation of 13·6 per cent., and for 48 tons per square inch an elongation of 11·9 per cent.

Curving Tests.—In addition to the preceding tests, a few rails are to be curved cold to a radius of not over 30 ft., and must, under this treatment, show no signs of injury.

All the tests specified are to be made when the steel is at approximately the temperature of the atmosphere, preferably at a normal temperature of 60° Fahr., but not under 32° Fahr. The test pieces must on no

account be heated, annealed, or otherwise manipulated, except by cutting and turning.

Number of Tests.—At least one rail out of every hundred must be subjected to the above tests, with the exception of the curving test, for which a smaller proportion may be selected.

The inspector may select defective rails for testing, provided the defects are not in the portions tested.

Chemical Analysis.—Should it be considered desirable to specify the chemical analysis (which the author considers unnecessary), the following results may be required :—

Carbon	=	0·40 to 0·50 per cent.
Phosphorus		not over 0·07 ,,
Sulphur		,, ,, 0·06 ,,
Manganese		not under 0·70 ,,
Silicon		,, ,, 0·08 ,,

The proposed tests are based on the assumption that the rails will have to bear the heaviest load per wheel anywhere in vogue—namely, 10 tons, whether the rail weighs 80 lbs. or more per yard.

For a lighter maximum load the conditions may be proportionately modified.

On the German State Railways the maximum load on locomotive wheels is 7·5 tons, and the rail hitherto in use weighs only 67·3 lbs. per yard, which is very light compared with English practice. The author is informed that a heavier type of rail is now gradually being introduced.

SPECIFICATION FOR TRAMWAY RAILS

For girder tramway rails the falling-weight tests may be less stringent than for railway rails, although it is very usual to impose the same conditions as for the latter. For a girder rail of, say, 80 lbs. per yard, one blow with a weight of 1 ton falling 15 ft. would be sufficient. On the other hand, a somewhat harder steel may with advantage be specified, say, from 44 to 50 tons per square inch.

The curving test may be the same as for ordinary rails.

CHAPTER VIII

PARTS OF LOCOMOTIVES, TENDERS, AND ROLLING-STOCK

Plates—Firebars, carriers, &c.—Wheel centres—Buffer rods, brake gear, and other forgings—Draw links, &c.—Piston and coupling rods—Crank pins, &c.—Cranks--Steel castings—Cast iron—Springs—Finished wheels and axles—Copper parts—Brass tubes.

In the present chapter it is proposed to deal with the various parts of locomotives, tenders, railway carriages, and wagons, not included under previous headings, more especially the class of material required for each.

Boiler and firebox plates for locomotives have already been considered, as well as axles and tyres in their rough (unturned) state; *finished* wheels and axles will be included in the present chapter, although it frequently happens that they are supplied by firms other than those which finish and erect the locomotives, tenders, carriages or wagons for which they are intended.

The following rules give generally the best English practice, as embodied in the specifications of leading engineers.

LOCOMOTIVES AND TENDERS

Smokebox, Tank, Cab, and General Plates.—When the material is *wrought iron*, the following tests are required:—*Tensile test*: breaking strength 20 to 22 tons per square inch; elongation in 8 in. 10 per cent.; contraction 15 per cent; two test-pieces are to be taken from each thickness of plate, representing each five or part of five engines and tenders, or one test for every six or less plates of each thickness; *bending test*: a test-piece cut lengthwise from the plate must stand being bent to a curve of which the inner radius is $1\frac{1}{2}$ times the thickness of the piece, without showing signs of fracture; *drifting test*: a hole drilled $\frac{5}{8}$ in. diameter through the plate must bear drifting out to $\frac{15}{16}$ in. diameter without causing signs of fracture.

If the plates are of *steel*, then the tests are as follows:—*Tensile test*: breaking strength 26 to 30 tons per square inch; elongation at least 20 per cent. in 8 in.; contraction at least 30 per cent.; *bending test*: a test-piece cut lengthwise or crosswise from the material, heated to a low cherry red, and cooled in water at 82° F., must stand bending double to a curve the inner radius of which is $1\frac{1}{2}$ times the thickness of the piece, without sign of fracture; *drifting test*: after heating and quenching the test-piece as above described, a hole $\frac{5}{8}$ in. diameter drilled in the same

must stand drifting out to $1\frac{1}{8}$ in. diameter before giving rise to cracks or fracture of the piece.

In the sequel, where bending and drifting tests are mentioned, it is to be understood that they are of exactly the same character as those just described—for iron and steel respectively—unless otherwise specified.

Main and Bogie Frame Plates, Buffer Beams, and Motion Plates.—When the plates are of wrought iron it is usual, in England, to specify Yorkshire iron; the tests are as follows:—*Tensile test*: breaking strength 20 to 22 tons per square inch; elongation 15 per cent. in 8 in.; contraction 20 per cent. lengthwise; crosswise, breaking strength 19 tons per square inch; elongation 12 per cent.; contraction 12 per cent.; in addition to this, bending tests.

For steel plates the requirements are the following:—Breaking strength, 26 to 30 tons per square inch; elongation 20 per cent. in 8 in.; contraction 40 per cent.; in addition to this, bending and drifting tests.

One bending and drifting test is to be made from each plate, and one tensile test from each set of engine and tender plates, or from every six or less plates.

Firebars, Carriers, Angles and other Sections, and forged Wheel Centres.—For *wrought iron*—*Tensile test*: breaking strength at least 22 tons per square inch; elongation 16 per cent. in 8 in.; contraction

22 per cent. For each section one tensile test-piece is to be taken from the material for every five or less engines and tenders.

In the case of wheel centres, one tensile test for each set of engine and tender wheels is sufficient.

For steel—*Tensile test*: 26 to 30 tons per square inch; 20 per cent. elongation in 8 in.; 30 per cent. contraction; *bending* and *drifting tests*.

Wheel centres, if not of wrought iron, are often of cast steel, and in that case a tensile strength of from 28 to 37 tons per square inch, with an elongation of 20 per cent. in 2 in., may be required; while a bar of the material machined square should stand bending cold, so that the two halves are parallel, and not more than the thickness of the bar apart, without showing any sign of fracture.

Buffer Rods and Bars, Brake Gear, Boiler Angles and Stays.—These are usually of wrought iron, with a tensile breaking strength of at least 22 tons per square inch, an elongation of 20 per cent. in 8 in., and a contraction of 30 per cent. One tensile test-piece should be taken from the material, representing one engine and tender.

Forgings for Motion Work (other than wearing parts), Valve Spindles, Fire-door Rings, Bridge Stays, Axle-boxes, Spring Buckles, Links and Hangers, Equalising Beams, Brake Gear, Buffers, and parts not otherwise specified.—*Best Yorkshire*

Iron: Tensile breaking strength 22 tons per square inch; elongation in 8 in. 16 per cent.; contraction 25 per cent.

Two tensile test-pieces to be taken from the various sections represented in the material for every engine and tender.

Chain Iron for Draw and Safety Links.—Tensile breaking strength 23 tons per square inch; elongation in 8 in. 20 per cent.; contraction 50 per cent.

One tensile test-piece to be taken from every ton or less of material.

Steel Piston Rods.—Tensile breaking strength 32 to 36 tons per square inch; elongation 25 per cent. in 2 in.; contraction 35 to 40 per cent.

One tensile test-piece from every ten rods should be taken.

Steel Slide Bars.—Tensile breaking strength 35 to 40 tons per square inch; elongation 20 per cent. in 2 in.; contraction 30 to 35 per cent.

One test-piece should be taken for every ten pairs ordered.

Steel Connecting and Coupling Rods and Crossheads.—Tensile breaking strength 26 to 30 tons per square inch; elongation 30 per cent. in 2 in.

The proportion of test-pieces should be the same as for piston rods.

Case-hardening Steel for Crosshead Pins, wearing parts of Link Motion and Crank Pins

with short overhang.—The number and character of test may be the same as for the preceding.

Steel Crank Pins of oil-hardening quality with two bearings or long overhang.—The tensile breaking strength before hardening should be at least 36 tons per square inch, and the elongation 25 per cent. in 2 in.

One test should be taken for every five pairs.

Steel Cranks.—Tensile breaking strength 30 to 34 tons per square inch; elongation 25 per cent. in 2 in. One test-piece should be taken for every engine or for every three pairs ordered.

Steel Castings.—For these a tensile breaking strength of 26 to 30 tons per square inch may be required, with an elongation of 12 per cent. in 2 in. Generally speaking, steel castings should be annealed, and the test-pieces taken *after* annealing. Steel castings should be very carefully inspected; they are very liable to contain blow-holes, and frequently these appear small on the surface, but open internally into comparatively large cavities. The test-pieces may be taken from the runners if practicable, or may be specially cast in one with the main casting.

One test-piece may be taken from every twelve or less castings, or one from each melting.

Cast Ironwork.—Cast iron for ordinary purposes is generally tested by bending under a dead load. A bar 3 ft. 7 in. long by 1 in. thick and 2 in. deep is placed

on bearings 3 ft. apart, and must sustain a load of 28 cwt., applied in the centre between the supports, without fracture. The deflection under a load of 25 cwt. should be at least $\frac{1}{4}$ in. If it is impracticable to obtain bars of 3 ft. 6 in. length, then the test-bars may be $14 \times 1 \times 1$ in., placed on bearings 12 in. apart, and loaded with 24 cwt. applied in the centre. This load the bar must bear without fracture, and with a deflection of not less than 0·07 in.

Cylinder metal should be of the best close-grained cast iron, twice cast, as hard as can be worked, and free from honeycombing and all other defects. Cylinders and valve chests should be tested by hydraulic pressure to $1\frac{1}{2}$ times the working pressure, and under this must be perfectly tight.

Engine, Tender, and Carriage Springs.—Flat springs for engines and rolling-stock must be of cast steel, of regular temper, with a breaking tensile stress of from 42 to 50 tons per square inch, with a minimum elongation of 10 per cent. in 2 in.

The thickest plates should be capable of bearing the lower stress, while the thinnest plates should stand the higher stress, and intermediate sizes in proportion. Spring plates are generally made with each side slightly concave, and with rounded edges. The springs must be capable of carrying twice the working load, for a period of ten hours, without losing camber. Each spring must be repeatedly pressed straight without

K 2

showing any permanent set; should permanent set at first occur, the test must be repeated until it is proved that no further set takes place. If eventually found to have too low a camber, the springs must be rejected.

One plate from every thirty to fifty springs may be selected for tensile tests.

The buckles should be of the best Yorkshire iron, of the quality previously specified for forgings.

Volute and Spiral Springs.—Each spring must be driven 'home' by a falling weight, or by a steam ram, without any diminution of the original height. A number of springs selected from the bulk must be subjected each to 1,000 blows from a steam ram, in every case driving the spring 'home;' if they permanently lose more than $\frac{1}{8}$ in. of their original height the bulk will be rejected.

Tensile tests and analyses may also be required.

All springs—flat, spiral, or volute—must be guaranteed for a period of 12 months' use.

Rivets.—The requirements for rivets have been previously given in Chapter VI.

Finished Wheels and Axles.—In addition to the tests and inspection necessary in the rough state, the leading dimensions must be carefully checked after the wheels have been pressed on to the axles, and turned and finished in all respects.

The most important dimensions are the gauge, the

diameter and length of journal, the outside diameter of the wheels, and the distance between the journals. Accurate templates and gauges for controlling these dimensions must be provided by the contractors. The work should be exact. In the case of the wheels, it is of chief importance that every pair of wheels should be of exactly the same diameter; slight deviations in the diameters of different pairs are not of so much importance. It is very generally specified that the wheel seats are to be turned with a taper of 1 in 100, and the wheels forced on by hydraulic pressure of not less than 50 tons.

COPPER PARTS

Firebox plates, stays, and rivets for the former, are the parts of locomotives very generally made of copper.

The copper used should have a tensile breaking strength of from 13 to 15 tons per square inch, with an elongation of 30 per cent. in 8 in. and 35 per cent. contraction of area. Strips cut from each plate should stand doubling up close without showing any cracks, and the rods for stays and rivets must endure a similar test.

A tensile test may be taken respectively from the plates and rods employed for one boiler. The tests must be made after the copper has been annealed. A chemical analysis of each tensile test-piece is generally required, which must show the material to contain not

less than 99·5 per cent. of copper, and not more than 0·15 per cent. of the remaining 0·5 per cent. may be arsenic.

BRASS BOILER TUBES

The brass used in the construction of boiler tubes should be the best solid-drawn material, consisting of about 70 parts of copper and 30 parts of the best spelter.

The ingots should be cast with a head at the upper end, which is subsequently cut off before the tube is drawn, so as to remove all foreign matter; and a shorter piece should also be cut from the lower end.

The centre hole of each ingot should be bored so as to get rid of any particles of the core which might otherwise remain.

Each tube must be annealed at both ends before leaving the manufacturer's works.

Tests.—The following tests are required by well-known locomotive engineers:—

(1) Each tube must stand an internal pressure (hydraulic) of 450 lbs. per square inch without showing any leakage. In the author's opinion, a less pressure than this would generally be sufficient, say, twice the working pressure.

Tubes selected by the inspector to stand—

(2) Flanging both hot and cold until the diameter across the flange is 25 per cent. greater than the diameter of the tube.

(3) Bulging cold until the diameter is increased by $12\frac{1}{2}$ per cent.

(4) Pieces cut out of the tubes to stand hammering flat longitudinally when cold.

ANALYSIS.—The brass used for the tubes must be shown by chemical analysis to contain not more than 1 per cent. of impurities.

NUMBER OF TESTS.—Two per cent. of the total order is usually selected for testing.

It is important that all the tubes should be of uniform section at any given point in their length.

For copper tubes the conditions are the same as for brass tubes, excepting, of course, the composition.

FINISHED WORK.—Regarding the inspection of complete locomotives, tenders, and rolling-stock, it is hardly feasible to give any detailed rules. Only practical experience can enable an engineer to form a judgment on the class of work he is called upon to inspect.

Careful attention should be given to riveted framing for locomotives and rolling-stock. It is of the utmost importance that the rivets should be well and accurately closed; there should be no cracked rivet-heads, and, wherever practicable, all the riveting should be performed by hydraulic power.

Locomotive boilers are tested under hydraulic pressure to at least $1\frac{1}{2}$ times the working pressure, and should be perfectly tight. Subsequently they

should be tried under steam to somewhat over the working pressure. There must be no leakage at any of the joints or stuffing-boxes.

For testing the distribution of the weight over the various axles, good firms have specially constructed weighing machines.

The following extracts from the specification of the Prussian State Railways for locomotives, tenders, and rolling-stock will be of interest to compare with the preceding data :—

Description of material	Tensile breaking strength	Elongation in 200 mm. (8″)	Tests other than tensile
Boiler and Frame Plates	Tons per sq. in.	Per cent.	
Of soft steel. . . . . N.B. Where only one figure for the tensile breaking strength is given, this always denotes the *minimum* limit.	21·6 to 26	25	Strips of from 30 to 50 mm. Width must stand doubling up completely without signs of fracture both lengthwise and transversely. The same strips heated to a dull red and quenched in water having a temperature of 82° F. must fulfil the same condition. Strips punched when red hot within a distance from the edge equal to half the thickness of the plate must not crack. The steel must weld easily without any special preparation.
Buffer Beams, Eccentric Rods, Equalising Beams, Parts of Valve Gear when not case-hardened, Foot-plates, Brake Rods, Handles and Hand-rails, &c.			
Of steel	21·6 to 26	25	Strips 30 to 50 mm. wide must stand bending through 180° round a bar of a diameter equal to half the thickness of the plate both before and after quenching.

Description of material	Tensile breaking strength	Elongation in 200 mm. (8″)	Tests other than tensile
	Tons per sq. in.	Per cent.	
Of wrought iron . .			
Bars and angles up to 10 mm. thickness.	22·9	12	Test pieces from flats 30 to 50 mm. wide, and also square and round bars, must stand bending round a bar of 26 mm. (say 1 inch) diameter without cracks or fracture (as shown in the sketch) to the following angles according to thickness :
From 10 to 15 mm. thickness.	22·2	12	
Over 15 mm. thickness .	21·6	12	

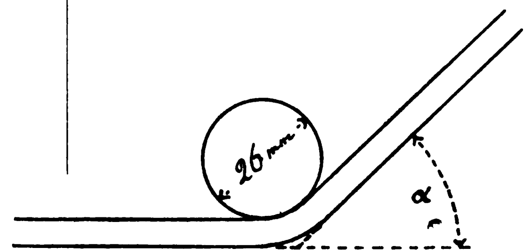


FIG. 17.

(*a*) *When cold*

For thicknesses from 8 to 11 mm.	50°
,, ,, ,, 12 to 15 ,,	35°
,, ,, ,, 16 to 20 ,,	25°
,, ,, ,, 21 to 25 ,,	15°

					For thicknesses up to 25 mm. 120° " " over 25 mm. 90°
Of wrought iron plates	lengthwise	across	length-wise	across	
Under 26 mm. thickness	22·2	20·9	12	8	Strips of from 30 to 50 mm. width must stand bending cold as shown in the preceding sketch to the following angles:
Over 26 to 28 mm. thickness	21·9	20·6			
" 28 " 30 " "	21·6	20·3			
" 30 " 32 " "	21·3	20·0			
" 32 " 33 " "	21	19·7			
					Length-wise / Across
					Up to 8 mm. thickness . . 110° 90°
					Over 8 up to 10 mm. thickness . 100° 80°
					" 10 " 12 " " . 90° 70°
					" 12 " 14 " " . 80° 60°
					" 14 " 16 " " . 70° 50°
					" 16 " 18 " " . 60° 40°
					" 18 " 20 " " . 55° 30°
					" 20 " 22 " " . 50° 25°
					" 22 " 24 " " . 45° 20°
					" 24 " 26 " " . 40° 15°
					Test strips heated to a dull red must stand bending over a blunted edge as follows:
					Lengthwise of the grain through the angle 180°
					Crosswise " " " 150°
Smokebox, Tank, Cab, and General Plates					
Of soft steel	21·6 to 26		25		Strips must stand bending through 180° round a bar of a diameter equal to half the thickness of the plate both before and after quenching.
Buffer-rods, Draw and Safety Hooks, Draw-bars					
Of wrought iron	21·6		18		Other tests same as for buffer beams, &c.
Of soft steel	23·5 to 27·9		20		

Description of material	Tensile breaking strength	Elongation in 200 mm. (8″)	Tests other than tensile
	Tons per sq. in.	Per cent.	
Firedoor Rings, Slide-valve Frames, Spring Buckles, Links and Hangers, Motion Work, Buffers, Pins and all welded parts			
Of wrought iron . .	22·9 to 21·6 (*vide* buffer, beams, &c.).	12	
Of soft steel . . .	21·6 to 26·0	25	Same as for boiler and frame plates, &c.
Cranks, Crank-pins, Connecting and Coupling Rods, Cross-heads, Piston-rods, Pistons, Buffers between Locomotive and Tender			
Of steel	31·75 to 38·1	2	
Stays, Chains, Rivets, Nuts and Bolts			
Of wrought iron			
Up to 25 mm. diameter .	24·1	18	The bars must stand without fracture: (*a*) Doubling up close at a dull-red heat. (*b*) Bending cold to a loop round a bar of a diameter equal to half the diameter of the
Over 25 mm. diameter .	22·9	15	

			A bar of 25 mm. diameter, 180 mm. long, with a screw thread cut in it, must stand bending double round a bar of 25 mm. diameter without showing signs of fracture. A round bar of a length equal to twice the diameter, when heated to the temperature at which the material is to be used, must stand hammering down to a third of this length without showing any crack. A strip of $1\frac{1}{4}$ to 2 inches width, cut cold from flat, square, round, or angle iron, must when red hot stand forging out to $1\frac{1}{3}$ times its original width, by means of a hammer-head rounded off with a radius of 15 mm., without showing any signs of rupture.
Wheel Centres *Of soft steel* . . .	25·4		A sleeve consisting of four segments is to be fitted into the bore. Into this a steel drift of square section, with a taper of 1 in 20, must be forced by six blows, having respectively a momentum of 1, 1·3, 1·6, 1·9, 2·3, and 2·6 foot-tons, for a bore of 5·7 in. For a bore of 5·1 in. five blows is sufficient. During this test the wheel-centre or disc is placed horizontally with the rim resting on timber supports. After this test no portion of the wheel centre must show any signs of injury.
Crank Axles *Of Nickel steel* . .	38	18	Contraction of area 45 per cent. at least. Percentage of Nickel 5 to 7 per cent.

Description of material	Tensile breaking strength	Elongation in 200 mm. (8″)	Tests other than tensile
	Tons per sq. in.	Per cent.	
Locomotive Tyres			
Of crucible steel . . .	44·45		The tyres must stand the impact of successive blows from a falling weight until the deflection expressed in percentage of the internal diameter amounts to $E = \frac{D}{100} - \frac{d - 65}{10}$, where D denotes the diameter of the tread and d the thickness of the rim when finished, expressed in millimètres; for inch units the formula would be $E = \frac{D}{4} - \frac{25\,d - 65}{10}$ Each blow must at first have a momentum of 9·7 foot-tons, and when the deflection under one blow is less than 0·4 in. the momentum is to be increased by 1·6 foot-ton.
Tyres for Tenders, and straight Axles for Locomotives and Tenders			
Of steel . . .	31·75		Falling-weight test for tyres as above, with the exception that the deflection is to be at least 12 per cent. of the internal diameter. N.B. For pressing wheels on their axles a pressure of 300 kilogrammes for each millimetre diameter of bore is required. Axles when placed on supports 1·5 metre (4·92 ft.) apart must stand eight blows each having a momentum for locomotives of 18 foot-tons, and for tenders of 13·6 foot-tons. The axles must be turned after each blow.

Flat and Spiral Springs			
Of Siemens-Martin or Bessemer steel, before hardening. If T = tensile breaking stress in tons per square inch, and E = elongation in per cent., then the formula $T + 1 \cdot 27E = 60 \cdot 3$ must be satisfied.	41·27	15	Any tempered spring plate, 3·5 in. wide by 0·5 in. thick, placed on supports 23·6 in. (say 2 ft.) apart, and loaded in the centre with 3,968 lbs. must show no permanent deflection. This applies to both ordinary and crucible steel. Every spring when finished is to be tested under an oscillating load, and under conditions similar to those obtaining when it is in use.
Of crucible steel . . . In this case the formula is: $T + 1 \cdot 27E = 66 \cdot 7$	47·6	15	
Cast Steel, hard . .	31·75 to 41·3	12	
Cast Steel, soft . .	23·5 to 27·9	20 in. 4 in.	
Cast Iron for Cylinders	11·5 to 15·25		
Copper Plates . .	14	38	Instead of elongation 45 per cent. contraction may be specified.
Copper Bars . . .	12·7	38	50 per cent. contraction.

CHAPTER IX

SOME REMARKS ON TENSILE TESTS AND ETCHING

Influence of dimensions on tests—Effect of relative position of fracture—Appearance of fracture—Connection between tensile strength, elongation, and contraction—Limits of proportionality and elasticity, &c.

ALTHOUGH it does not come within the scope of this work to write a treatise on the strength and testing of materials, there are some points of immediate practical interest to the inspecting engineer in connection with the subject on which the author thinks it desirable to offer a few remarks.

Influence of Dimensions of Test-piece on Results.—The tensile breaking stress of steel is only slightly affected by the sectional area of the test-piece, but has a tendency to be greater—with the same material—for a small sectional area than for a large one.

With a given sectional area of test-piece the relative total elongation after fracture increases as the test-length diminishes. The reason for this is, that a large proportion of the total elongation is confined to

that part of the test-piece near the point of fracture, on either side of the latter. This portion of the elongation takes place after the maximum load is reached and during the period of local contraction. The length over which this local contraction occurs is nearly the same for long and for short test-pieces, consequently its ratio to the total test-length decreases as the latter increases. A test-piece, for instance, which shows a relative elongation of 15 per cent. in 8 in. will show, perhaps, 20 per cent. or more in 2 in. With soft material, having a high contraction, this difference in the relative elongation will be greater than with a harder material with lower contraction.

This, it must be distinctly understood, applies on the assumption that the section remains the same, while only the test-length varies.

Professor Martens has, however, found that when the test-length varies according to a simple law with the sectional area, then the relative elongation is the same—with similar material—for test-pieces of various dimensions. This law is that the test-length must be proportional to the square root of the sectional area; that is, for cylindrical bars, to the diameter, and, for square bars, to the side.

If, therefore, with a test-piece of $\frac{3}{4}$ in. diameter, a certain relative elongation be required on a test-length of 8 in., and, owing to circumstances, it is only possible to obtain a test-length of 4 in., then, in order to arrive

at comparable results, the diameter in the latter case should only be $\frac{3}{8}$ in.

Influence of Relative Position of Fracture.—As previously mentioned, if the fracture of a test-piece takes place eccentrically, that is, not in the middle of the test-length, but considerably nearer to one of the ends, the relative elongation and contraction are thereby affected; they are lower than if the fracture occurred in the middle. If the deviation from the middle is not great, its influence is, of course, inappreciable; but if the fracture takes place close to one end, then the results may be considerably affected.

Besides reducing the elongation and contraction, an eccentric fracture, when very near one end of the test-piece, tends to increase the breaking strength, but for practical purposes only to a negligible extent.

Appearance of Fracture.—The appearance of the fractured surface of a test-piece is generally supposed to give a clue to the quality of the material; but this is only the case to a limited extent. The appearance of the fracture frequently depends on the manner in which the test-piece breaks, and—as the author has observed in the case of rail steel—on the amount of contraction. For instance, two test-pieces may, when broken, show the same tensile strength, the same relative elongation, and the rails from which they have been cut may have stood the falling-weight tests equally well; if, however, one of these has a considerably

greater contraction than the other, the appearance of the fracture in the two pieces will be quite different—that with the greater contraction showing a much finer grain, although the material of both is essentially of the same quality.

Connection between Tensile Strength, Elongation, and Contraction.—For the same class of steel the relative elongation varies generally in an inverse ratio with the tensile strength, but there are many exceptions. Also, generally speaking, the contraction increases with the elongation, but even, for a certain make of steel, very irregularly. It is possible to produce steel having a very low relative elongation and very high contraction. This is the result of cold drawing. On the other hand, two samples of steel may have, as nearly as possible, the same tensile strength and the same relative elongation, yet the contraction of the one piece may be twice as great as that of the other.

Comparatively slight flaws affect the contraction very considerably, especially when near the surface of the test-piece; the elongation is also appreciably influenced by such flaws.

As a guide to the relations which should exist between the tensile breaking stress and the relative elongation, a formula originally proposed by Professor Tetmayer is frequently employed. This is based upon the work necessary for the fracture of a test-piece, and assumes that for steel of a given class this work is constant.

Professor Tetmayer's formula is:

$$\text{T} \times e = \text{constant},$$

where T denotes the breaking tensile stress in tons per square inch and e the relative elongation in percentage (in 8 in.).

For rail steel the constant recommended is 571·45 (or strictly speaking its equivalent for kilogrammes per square millimètre), hence:

$$\text{T} \times e = 571{\cdot}45.$$

Another formula proposed with the same purpose is:

$$\text{T}^2 \times e = 16126.$$

The latter represents less stringent demands on steel of higher tensile stresses than Tetmayer's formula.

Limit of Proportionality, Limit of Elasticity, and Breaking-down Point.—The limit of proportionality is the point up to which stress and elongation are proportional. In practice it is seldom specified, and must be determined by very careful and frequent observation of the load and corresponding extension. The limit of elasticity is that point at which permanent set begins. The breaking-down point, which lies slightly beyond the limit of elasticity, is that at which a so-called flow and contraction of the material commences, and is generally marked by the fact that the load remains for an appreciable time constant, and often diminishes while a further elongation of the test-piece takes place. This can, as a rule, easily be observed on most testing machines, and is generally noted as the

limit of elasticity, although the latter in reality occurs at a slightly lower stress.

Etching Rail Sections.—For the purpose of testing the homogeneity of rails by etching, it is most convenient to have slices cut out of the rails at right angles to the longitudinal axes, say $\frac{3}{4}$ to 1 in. thick. One or both surfaces of each slice should be uniformly polished, and then placed in the etching fluid. Hydrochloric or sulphuric acid, diluted with water, may be used, but very good results may be obtained in a short time by means of a solution of iodine and iodide of potassium in water, in the proportions by weight of 1 part of iodine, 2 parts of iodide of potassium, and 10 of water. By the action of this solution a good etching may be obtained in from twenty minutes to half an hour. When the steel is removed from the fluid it should be thoroughly washed and dried.

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